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Application of Some Basic Statistics to a Few of the Problems of the Glass Container Industry

By

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INTRODUCTION

As a preliminary, in studying the problems it presents, it would be advantageous to first give a brief description of the process of making glass containers.

The main ingredients of container glass are sand, soda, limestone, and syenite or feldspar. Ingredients used to a lesser degree are barytes, salt-cake, flourspar, arsenic, nitre and coloring agents. The main components will vary very little between flint and colored glass. These materials are shipped in carload quantities and have definite chemical and physical property specifications. The materials are weighed and mixed into several ton unit batches. These batches are loaded in large hoppers and transported to the rear of the glass melting furnace where it is slowly fed onto the molten glass contained in the tank. The tanks are continuous furnaces fired by either producer or natural gas, or oil to temperatures above 2700°F. and will produce around 150 tons of finished glass every 24 hours.

After the batch enters the furnace, it becomes molten glass by a combination of melting and solution reactions. During the time it is in the furnace, it must become completely melted, homogenized, and free of bubbles before it enters the nose area where the glass temperature is dropped preparatory to it being delivered to the forming machines. Final working temperatures are established in the channel or forehearth extending from the nose as the glass is delivered to the forming machine.

At the end of the forehearth, the properly conditioned glass enters a well with an orifice in the bottom where it is forced out by gravity aided by a plunger. A definite weight of glass is cut with automatic shears into gobs which are fed into the forming machine. The transit time of the glass from the back end of the furnace to the machine is in the order of 18 to 24 hours.

The bottle is formed from a gob of molten glass on an automatic machine which essentially duplicates the operations of a glassblower as the glass is shaped by air in iron molds.

From the forming machine it is fire polished and moved into the lehr for annealing. The time spent moving through the lehr, usually about an hour, is proportional to the amount of glass in the bottle as annealing removes the strain from the glass by a controlled rate of cooling.

From the lehr the bottles are surface treated according to specification, inspected both by machine and by hand, packed, and moved to the warehouse for shipping.

It would be useful here again to explain a few of the control checks made on the glass and on the operation from beginning to end. This will help us better understand the illustrations that will be used in this paper.

To cover the checks made on both the composition of the glass and the quality of the ware, let us go back to the raw materials and start through the flow chart again. Each railroad car or truckload of material that comes in is sampled and the particle size distribution is determined. Chemical analyses precede each car of material of the type whose composition is subject to variations. Batch house scale calibration and maintenance is a continuous operation. Because of the difficulty and time required to carry out chemical analyses on finished glass

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Table I

Material	No. cars at high peak	No. expected by random	Sigma Dev.	No. cars at low points	No. expected by random	Sigma Dev.
Soda	29	26	0.97	31	26	1.35
Supplier A	18	11	1.97	10	11	–0.15
" B	4	9	–1.56	13	9	1.15
" C	3	2	0.21	2	2	0
" D	2	3	–0.21	1	3	–1.04
" E	2	4	–0.52	5	4	0.25
Limestone	17	15	0.76	14	15	–0.23
Syenite	5	4	0.32	5	5	0
Calumite	2	5	–0.85	4	6	–0.46

they must be determined indirectly if control is to be maintained over the continuous operation. Such analyses are calculated daily from the results of physical measurements. These properties measured routinely with high precision are density, coefficient of expansion, and the viscosity-temperature characteristics of the glass. This data is recorded and plotted on conventional control charts.

A change in a physical property indicates a change in glass composition. As the effect of composition on each property is known, the composition can readily be calculated and controlled.

Routine data is also taken on seeds, color, homogeneity, fluorescence and tank operation. It will be these variables plus a few topics that have not been mentioned yet, that will be dealt with in this paper. These are all indirect measurements of quality. The direct measurements of product quality are made by attribute inspection of newly finished ware following the procedures established in Military Standards 105A. However, since these are very familiar techniques, they will not be gone into at this time, but rather this paper is concerned more with quality control achieved indirectly.

PROCEDURES AND RESULTS

Four separate operations of the glass plant will be considered. In each, an attempt will be made to show how the application of statistics helps to ultimately and indirectly control the quality of the ware.

I. Probability and Student Fisher T Distribution as Applied to Density Variation

For some time, the density variation in the glass in one plant had been greater than previous operation indicated it should have been. These variations in density are caused by variations in glass composition and can be caused by either an error in weighing in the batch house or by the variation in the quality of the different materials being used. After extensive work had been done in and around the batch house, checking the scales and checking to see if carelessness caused the variation in density, it was decided that the error was not in the batch house.

The possibility of raw material variation was determined by utilizing records of all incoming shipments of soda, limestone, syenite, and calumite for a year's time. Sand wasn't considered because it came from the same supplier and arrived every day at the plant, hence it could not be the cause of this weekly variation in density. The remaining materials were not considered because their total weight is a very small percentage of the total batch.

The density during this period had peaked near out or out of control limits approximately every seven days. To try to tie these peaks down to a certain material, a procedure was used of recording specifically those cars of material that were unloaded for a two day period before the peaks, and for a two day period after a low point. After recording all these points and separating them into the separate raw material class it was necessary to find by probability how many of each raw material would be expected by random and then to check to see if there was a significant difference between that actually found.

The total weight of the individual raw materials per batch was found and then the percent that each individual component is of the total was calculated. These ratios were then multipled by the total number of cars found to get the number expected by random sampling. These totals were compared against that actually found in Table I along with the ± sigma deviation from the mean. All raw materials of each different type came from a single supplier except for soda, which came from five suppliers.

It would perhaps be of help here to run through a complete calculation to help clear up any questions. It was found that for the year in question there were 53 carloads of raw materials occurring on two day periods before peaks in density. The total weight of these four materials in a batch is 1511 pounds. Since soda makes up 753 pounds of this, it is 49.8 percent of the total. Hence on 53 carloads of raw material, 26 carloads of soda would be expected.

$$\text{By } \frac{753}{1511} \times 53 = 26$$

$$P \times n = n_o$$

Since 29 actually appeared, to test significance, the Student-Fisher T distribution

$$t = \frac{(x\text{-}u)\ (N\text{-}1)^{1/2}}{S} \quad \text{where } S = \sqrt{npq}$$

is used, a sigma deviation of 0.97 deviation was found, which is well within the range of +1.96 sigma deviation which set up 90 percent confidence limits. However, Supplier A of soda was found to appear 18 times while it was expected to appear only 11 times. This sigma deviation significance test came out to be +1.97 which places Supplier A right on the edge of significance. While on the first test Supplier A could not be accused of an

Table II

No. of Weeks X	Average amount of gas consumed in 24 hrs. (per 1000 cu. ft.) G	Average load in tons of glass per 24 hrs. Y	Average Temperature T	Q Average Thermal Performance
—	—	—	—	
2	722	98.20	2560	5.56
3	707	104.35	2567	4.84
4	696	98.87	2525	4.99
5	737	110.08	2517	5.02
6	701	102.54	2585	4.82
7	727	108.21	2516	4.50
8	682	104.56	2507	4.71
9	704	98.34	2565	5.10
10	700	96.63	2570	4.92
.	.	.	.	.
.	.	.	.	.
.	.	.	.	.
233	846	125.91	2615	5.45

inferior product, if on a second test, it again fell on the border line, it would have to be attributed to more than chance and steps could be made in that direction.

Hence, in conclusion, it has been shown how probability and Student-Fisher T distribution have helped to tie down one variable that could be affecting the density. It also almost completely exonerates the remaining raw materials as no other material even approached the limits.

II. Equation Fitting and Prediction of Furnace Q Values by Simple Statistics

The second method to be considered is a statistical deviation of a furnace efficiency and operational formula.

In the 1944 issue of the *Journal of the Society of Glass Technology*, there appeared a formula

$$Q = \left(\frac{GH}{AK_aKt} - \frac{Wc}{AK_a}\right)$$

that was to be used to test the thermal performance of the furnace. It was later revised and changed by D. E. Sharp and L. B. Ginter in THE GLASS INDUSTRY, 1954 to

$$Q = \frac{1.16}{M}\,\frac{(G - CW)}{K_a}$$

which can be easily derived from the former formula. Work was done at Brockway Glass along these lines and while yet in the experimental stage it shows promise of being future control in furnace operation.

In the latter formula, the letters signify the following:

Q—quantity of heat required per second to maintain 1 ft.² of glass surface at 2550°F.

G—quantity of fuel used per 24 hours in Therms.

K_a—A constant involving area and temperature, dimensionless

C—quantity of heat required at reversing value to melt raw materials to yield 1 lb. of glass and raise it to 2550°F.

W—Tonnage pulled per day

M—Area constant. Corrects furnace area and changes it to a standard 600 ft.²

Knowing these will give a better understanding of what is to come. As can be seen from these variables they will account for many of the changes in furnace operation. Furnace control is important not only for cost sake, but also for the quality of the final ware. In this connection, it is desirable to know for any tonnage and temperature what amount of fuel should be used to most efficiently run the furnace.

To set up an equation including all these variables, the above variables were recorded into a table. (See Table II.)

After all data had been recorded, it was coded by using false zeros. The squares and products, taken in pairs, of these qualities are next calculated and summed giving totals $S(x)$, Sy .... $S(x^2)$, $S(y^2)$ .... $S(xy)$, $S(xz)$, and so on. The average values of a variable can be obtained by adding to the false zero the value of the appropriate sum divided by the number of observations: For example, this average value of the gas consumption:

$$G = 750 + \frac{S(G)}{233} = 750 + \frac{815}{233} = 753.5$$

The sum of the squared deviation of the observed values from the average value of each variable is obtained by subtracting from the sum of the squared deviations from the false zero the square of the sum of the deviation from the false zero divided by the number of observations. For example:

$$S(G_1 - \bar{G})^2 - S(G^2) = S(G)^2/233 = 6713 - \frac{(815)^2}{233} = 3863$$

To find the equation of the form $G = G_o + ax + by + dt$ which best fits the data, first form the equation by the following rule. Write down the equation three times excluding the constant term G_o,

$$G = ax + by + dt$$
$$G = ax + by + dt$$
$$G = ax + by + dt$$

then multiply the first through by x, the second through by y and so on, and place the summation sign in front of each combination of variables. This gives:

$$S(Gx) = a\,S(x^2) + b\,S(xy) + d\,S(xt)$$
$$S(Gy) = a\,S(xy) + b\,S(y^2) + d\,S(yt)$$
$$S(Gt) = a\,S(xt) + b\,S(yt) + d\,S(t^2)$$

After all the data had been calculated an equation in the form of

$$G = G_o + ax + by + d(t-2550)$$

was found where x is age of furnace, y tonnage and t is temperature. G_o is the gas consumed at no load values and a, b, and d are constants evaluated by statistics. The final form was:

$$G = 753.5 + .85x + 5.12y + .09(t-2550)$$

Although this equation is useful as a guide in the control of a furnace it can never or will never replace the experienced engineer.

A method has been set forth by C. E. Gould in the

1952 issue of The *Journal of the Society of Glass Technology* and later revised by D. E. Sharp and L. B. Ginter in the 1954 issue of THE GLASS INDUSTRY, to set up a control chart for the operation of a furnace. This method uses the variables of area, temperature type of block used in furnace, iron content in glass, and the depth of the glass in the melting area. To show how these variables are used in setting up control on a furnace, the following example is shown:

In making this control chart the main factor to be calculated is the aging factor (a). This aging factor actually is the slope of the linear plot of the Q values plotted entirely dependent on the amount of fuel used. The aging factor will set up a control on the amount of fuel consumption with age and may for all practical purposes be considered as taking place at a uniform rate, if the average rate of tonnage production is reasonably uniform throughout the campaign.

The effect of temperature on the aging factor "a" was found to vary with the furnace area. It is found from: $-\log a = 3.94 - \frac{B}{T}$ where B is a function of the melting area of the furnace and is found from a graph given in Gould's report. Each of the other corrections are found from formulas in this order.

Let us take for example, a furnace of 544.5 sq. ft. area running at an average temperature of 2800°. This furnace has sillimanite blocks at its flux line, an iron content of .17 per cent, a 3 ft. depth and an original Q of 5.00.

Knowing this, the slope of the aging factor can be calculated as well as the ± 3 sigma limits within which the Q values must fall. By this method the slope was found to be .0122 for the Q factors. By actual experience over a four year furnace life, the slope was found to be .0120, which is very close.

This then closes out the second case of how statistics can be used on a very practical problem. This is a statistical analysis of the furnace operation, and a calculation for a control chart for it.

III. Multiple Correlation and Beta Coefficients Applied to Variation in Orifice Size

The third part of this paper will deal with the application of multiple correlation; i.e., to the problem of change in size of the orifice. As was mentioned earlier, the orifice is the place in the feeder from which the glass is ejected immediately before entering into the moulds. The orifice, the thrust of the needle, and the tube height control the size and shape of the gob. The orifice will either erode or corrode during a long run on any one job. The objects of the study are to find out whether time or temperature has the most effect on the wear in the orifice, and to find a method by which it can be predicted when the orifice should be changed.

Since the orifice can't be measured for change in size during actual operation, it is done indirectly by measuring the change in tube height. For any given temperature, as the orifice wears away, the tube height must be dropped to maintain a constant weight gob of glass. Through this relationship, and knowing the length of time and temperature at which the gob was run, the effect of time and temperature on the orifice size can be determined.

The equations used for the determination of the multiple correlation factors are:

$$S(yx_1) = b_1 S(x_1^2) + b_2 S(x_1x_2)$$
$$S(yx_2) = b_1 S(x_1x_2) + b_2 S(x_2^2)$$

where y = change in orifice (tube height)
x_1 = time
x_2 = temperature
b_1 = effect of time on orifice considering temperature
b_2 = effect of temperature on orifice considering time

The correlation coefficient from this is found by

$$r_1 = b_1 \sqrt{\frac{S x_1^2}{S y^2}}$$

Data had been recorded for approximately two years for different types of feeder operation. For the study of orifice change with temperature and time, the temperature at which the job was run, the length of time it was run, and the change in tube height were recorded. However, other things were taken into account before this data was recorded. For a period to be studied, it was found essential to have a run of at least 5 days, a new orifice, and a constant tube and needle setting. If these four requirements were met, then data is taken on the above mentioned three variables, coded and set into a table to make final calculation. The data was set up as follows:

Table III

Length of Job	Tube Change	Temperature
7	6.25	50
10	25.00	90
13	18.75	90
.	.	.
.	.	.
.	.	.
10	18.75	100

Calculations were made in the usual manner and the results were as follows:

	Con. Coeff.	Needed for Significance
Orifice vs. time with temperature	48.81	24.94
Orifice vs. temperature with time	38.35	27.93
Orifice vs. temperature and time	84.21	....

As can be seen by the table, the multiple correlation coefficient for orifice size vs. time, taking into account the temperature, is the highest one and also the correlation needed for significance is the lowest. This would seem to indicate that the wear on the orifice is more a matter of erosion rather than corrosion although the latter is an important part.

With all other variables held constant as referred to in the procedure, the two variables, time and temperature, account for 84.21 per cent of the change caused by unknown curves. It was also noticed that for temperatures of over 2050° F, the time an orifice can be left in without effecting its size excessively was approximately 6 to 8 days. For temperature under 2050° F, 8 to 10 days

Table IV

Date	Defect A	Seed	Soft Pt.	Flow Pt.	Density
Jan.	....	8	....	....	....
Feb.	13, 22	....	25	4, 19, 25	1, 22, 25
Mar.	3, 27	6	3	6	6, 21, 27
Apr.	28	28	2, 25	2	13, 16, 25
May	19	10, 19, 25	19	....	10
June	8	5, 11	8	....	5

seemed the best length of time. Up to this length of time for either temperature, the orifice doesn't change enough to be of practical importance. However, in practically all cases tested over the two year period it was found that after this length of time the tube length had to be changed to account for the change in orifice.

Another useful but little used statistical tool used in this particular work was the use of Beta Coefficients. The coefficients of regression of the multiple correlation regression equation indicate the increase in the dependent variable resulting from a unit increase in the indicated independent variable. However, the various independent variables are often expressed in different units making a direct comparison of the coefficients impossible. The coefficients of multiple regression may be made comparable by dividing each variable by its own multiple regression equation.

$$Y = a + b_1x_1 + b_2x_2$$

becomes

$$Y = a + \frac{b_1x_1}{\sqrt{y}} + \frac{b_2\,x_2}{\sqrt{x_2}}$$

and therefore

$$\phi = b_2\,\frac{x_2}{\sqrt{x_2}}$$

where ϕ = Beta Coefficients

Results:

	Stand Dev.		Beta Coeff.
Time (x_1)	2.41	$y_{1\cdot2}$	.270
Temperature (x_2)	39.14	$y_{2\cdot1}$	.278
Orifice (y)	9.32		

The results of these Beta coefficients are read: for $y_{1\cdot2}$, for every change in a unit to time i.e., every 24 hours, there is a unit change of .270 of 1/16 of an inch in the tube length or conversely a proportional change in orifice size. Also for every unit change in temperature, i.e., every °F, there is an increase of .278 of 1/16th of an inch in tube length. These Beta coefficients are very useful calculations and can be used in connection with ± 3 sigma limits. For example, if limits are set on when the orifice size has gone out of control, it is possible by this statistical tool to predict approximately when this will happen and correct it before any real harm has been done in connection with the manufacture of bottles.

IV. Simple Correlation and Data Grouping to Control Production Variables

The fourth and final use of statistics in the indirect control of glass quality is a general statistical and graphical study of the variation in the physical properties of glass with time and their relationship to one another. The variables that will be considered are seed count, blister count, flow point, softening point, nose temperature, and batch weights vs. density and a particular ware defect. These variables all affect the quality and the inherent characteristics of the particular glass.

This problem was approached by graphing and then computing the correlation coefficients of the variables in relationship to one another. Also extensive work was done with control limits on the graphs, to determine and attempt to account for the instances that the variables went out of control. Cullet, water changes and errors in the batch houses were used in attempting to find the explanation along with other standard procedures.

A trial range was picked which included 165 days (excluding shutdowns) to which the work was applied. On each of these days samples were taken, coded, and set down in table forms.

Since there is a tendency for the day-to-day functions of the variables to be erratic and to vary over a wide range, an attempt was made to eliminate the sudden changes of the variables and to record only trends in the variables. This was done by recording the variables in overlapping three day ranges. From these totals of overlapping averages, the correlation coefficients were calculated using the formula:

$$r = \frac{n\,\Sigma\,x\,y - \Sigma\,x\,\Sigma\,y}{\sqrt{[n\,\Sigma\,x^2 - (\Sigma x)^2]\;[n\Sigma y^2 - (\Sigma y)^2]}}$$

The control limits were calculated in the usual manner, by taking ranges and then, follow set procedures to form ± 3 sigma limits. Following the calculation of these limits, the limits were applied to the graphs of the variables. When the control limits were applied to the graphs it was found that the points out of control fell in distinct groupings from all the graphs. These were recorded as shown in Table IV.

Cullet and water changes were studied to see what effect they might have on the above variables going out of control.

The two variables that were to be checked the closest were a particular bottle defect and density. This defect occurred quite seldom but was in the major classification and could cause large scale ware rejection if not found. Since at this time no method was available for accurately determining the cause of this defect, the problem was approached through correlation. Density, the other important variable, was considered because it was thought the change in batch could be causing the variation in the other variables. The correlation of the defect and density versus other variables are shown in Table V.

It is obvious that for all correlations of density vs. other variables, a high correlation was found in all but one case, the flow point. As any density change indicated

Table V

	Flow Pt.	Blisters	Seed	Nose Temp.	Softening Pt.
Defect vs.	—.154	.694	.523	—.0374	.0161
Density vs.	.0595	.21	.434	.64	.1675
Density vs. Defect		.2699			

Table VI

Date	Cullet Change	Change in Variables
Jan. 3	700# - 500#	Jan. 8 (+5 days) Seed at low point
Jan. 25	500# - 300#	Feb. 4 (+9 days) High point flow point High point density
Feb. 10	300# - 700#	No changes
Feb. 12	700# - 300#	Feb. 13-22 (1-10 days) High point Defect A Feb. 22 (+10 days) High point density Feb. 15 (+3 days) Low point flow point Feb. 20 (+8 days) Low point soft point
April 9	300# - 500#	April 24 (+5 days) High point soft point April 26 (+7 days) High point Defect A April 26 (+7 days) High point Defect A April 25 (+6 days) High point density
May 16	500# - 300#	May 19 (+3 days) High point soft point May 19 (+3 days) High point seed May 25 (+9 days) High point seed May 19 (+3 days) High point Defect A
June 14	300# - 500#	June 15 (+1 day) High point seed

a composition change, it would appear that overloads of one or two components which caused density increases and resulting workability troubles predominate over other types of batch errors. These components also have little effect on the flow point, and one of these has little effect on the softening points.

None of the variables seemed to tie up with the defect to any great extent except for seed (after March 1), blister count and density. When seed was correlated against the defect for the whole period (Jan. 3-June 26) the average correlation was very low and worthless, being only .0985. However, due to the apparent way the graphs of these two variables seemed to be so very much alike after March 1, a second correlation coefficient was calculated for this period and this time a very high correlation was attained of .486. The only explanation that can be given for this defect going out of control during the latter part of Jan. and all of Feb. and yet having the seed stay the same is that there is yet another outside variable that can affect Defect A and let seed remain constant. It was thought that blister count and the defect number would correlate high because of the fine line drawn between the definition of the two. This seemed to hold out well as the correlation coefficient between the two comes out to .694, which was one of the highest values calculated.

The correlation was run between softening point and seed count and a high coefficient was found. This is due to the fact that the more fluid the glass the faster the seeds will rise to the surface. This will not be true if seeds are formed in the nose or feeder by "reboil" where the glass has too high a viscosity. It would thus appear that high seed counts can be attributed to insufficient fining time in the melter at least 50 per cent of the time.

As can be seen by a careful study of Table IV, the occasions that the variables were out of control fell into definite periods. Perhaps the biggest surprise of this work was the tie up found between cullet changes in the batch and the variables being out of control. The change in variables vs. cullet change can be seen in Table VI.

Within a ten day period of all cullet changes, except that of Feb. 10, all the above figures reached either a high point or low point, as shown in the above table. These 17 days accounted for 43.0 per cent of all the days that the variables were out of control. 33.3 per cent of the other days were low points in the variables, occurring when the same poundage of cullet had been used for a reasonable length of time. This leaves 23.1 per cent of the points unaccounted for in the cullet theory. These findings confirmed the observations that had been reported by the Production Department for many years.

Although this last method cannot be considered purely statistical, these methods of grouping and eliminating just described have proved very useful in indirect quality control and are used extensively at Brockway.

CONCLUSIONS

It has been shown how different methods of statistics can be used in indirect quality control of the glass container industry.

First, probability and significance tests were considered in controlling the variation of quality of incoming materials which were in turn affecting density.

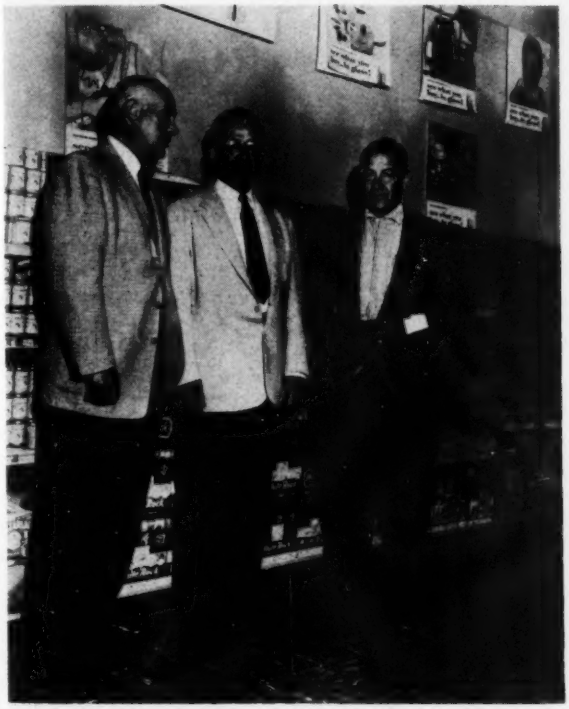
Second, the evaluation of furnace performance was calculated by methods of least squares and by other basic statistical methods, i.e., standard deviation, variance, and control limits.

Third, by multiple correlation and Beta coefficients the problem of orifice change in gob operation was considered. (*Continued on page* 652)

G.C.M.I. Meets Near America's First Glasshouse

• THE SEMI-ANNUAL MEETING of the Glass Container Manufacturers Institute, Inc. was held at The Cavalier, Virginia Beach, Virginia, from Monday, September 30 through Thursday, October 3.

In opening the meeting, Edmund F. Ball, board chairman and president of Ball Brothers Company, and president of G. C. M. I., told the assembled glassmen that, since 1958 will mark the three hundred and fiftieth anniversary of the establishment of the glass industry in America, it seemed particularly fitting that the glass container industry should meet only a few miles from the birthplace of the industry, Jamestown, Virginia. On the third day of the meeting the members visited the site of the original glasshouse which is a part of the Jamestown Festival.



The program committee consisted of (left to right) C. G. Bensiger, Owens-Illinois Glass Company, J. C. Feagley, Armstrong Cork Company, who served as chairman, and J. S. Heuisler, Maryland Glass Corporation.

Briefly reviewing the history of the first English settlement in North America, Mr. Ball, in referring to the glasshouse, pointed out that from one tiny wood-burning furnace the container branch of the glass industry alone has become one of the country's most important industries, currently operating two hundred and seventeen furnaces in some ninety glass container plants throughout the country.

Mrs. Joseph C. Feagley is shown blowing a glass bottle at the Jamestown, Virginia, replica of the glasshouse erected there almost 350 years ago by America's first colonists. Mr. Feagley (left) served as chairman of the G.C.M.I. semi-annual meeting's program committee.

Turning to the current business position of the industry, Mr. Ball stated, "Domestic shipments of new glass containers by the forty glass companies which are members of G. C. M. I.—representing approximately 95 per cent of the industry—reached an all-time monthly high of 16,738,000 gross in August. Further, August

Mr. and Mrs. Edmund F. Ball at The Cavalier, Virginia Beach. Mr. Ball is president of the Institute.

Ladies committee members were (left to right) Mrs. J. H. Funkey, Mrs. K. C. Frazier, Mrs. S. V. Tuttas, and Mrs. T. J. Conry.

shipments were up 13.1 per cent over the previous monthly high of 14,796,000 gross scored in August, 1956.

"Shipments for the first eight months of this year totaled 90,188,000 gross compared with 87,238,000 during a corresponding period last year, an increase of 3.4 per cent.

Richard L. Cheney, executive director of G.C.M.I., Edmund F. Ball, president of the Institute and president and board chairman of Ball Brothers Company, Inc., Joseph C. Feagley, vice-president of the Armstrong Cork Company, and Victor L. Hall, general manager of G.C.M.I.

"The remarkable August showing is largely accounted for by increases of 12 per cent in shipments for food container end uses, and 11 per cent in the shipment of bottles and jars for toiletry and cosmetic end uses."

Market research and promotion continues to be of paramount interest to the glass container manufacturers. R. L. Cheney and his associates reported in detail on the advertising and promotion program.

With regard to this phase of the Institute's activities there seems to be complete agreement in the industry that real progress has been made and that among the consuming public many people are considerably more glass container conscious today than they were when the effort was initiated.

The golf committee: (left to right) S. V. Tuttas, Crown Cork & Seal Company; P. I. Heuisler, Jr., Maryland Glass Corporation; and R. M. Ulmer, Armstrong Cork Company.

GALLO GLASS STARTS CONSTRUCTION AT MODESTO

Joseph E. Gallo, President of Gallo Glass Company, announces that construction by that company of a large, modern glass bottle factory has begun at Modesto, California.

The furnace will be of Hartford-Empire design, and all machines used will be the six-section I. S. Type.

The general contractors are Larsen & Larsen, Inc.

The plant will be erected on a twelve-acre site adjacent to Modesto, California. Approximately 200 persons will be employed.

Among the reasons Mr. Gallo gave for choosing Modesto as the location for the plant is the availability of labor, excellent living and housing conditions and the fact that it is located in the center of the San Joaquin Valley, which will enable it to dispose of its output in that area with a resulting freight saving.

Modern Concepts of Fracture and Flow
Part I: Equilibria in Particulate Bodies

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Second Installment

VII INFLUENCE OF THE THIRD DIMENSION

IT MAY BE REMARKED that the equilibria discussed so far concern configurations of particle quartets that are maintained in a plane. In three-dimensional space, the stable equilibrium configuration of such a quartet would assume the tetrahedral shape. The two-dimensional problem is, however, much simpler than the three-dimensional one and is therefore much better adapted for elucidation of the concepts than is the latter. With these concepts explained, the way is clear for expanding them to apply to the general three-dimensional case.

To maintain the two-dimensional configuration in three-dimensional equilibrium, it suffices to consider a third particle pair that has the same center as the other two pairs, the axes of the three pairs being mutually orthogonal.

This configuration can be seen in Fig. 7 where the quartet of particles, 3, 4, 5, and 6 form the two-dimensional configuration with particles 1 and 2 forming the additional pair.* This configuration appears in Fig. 1 in which two of the quartet of particles belong to each of two rings in opposition, while the center particle with its mirror image across the plane of the quartet constitutes the additional pair.

It is advisable at this point to change the axes of reference. Let the x axis be that of the additional pair, and the y and z axes those of the sides of the quartet formed by the other four particles as indicated in Fig. 7 rather than the diagonals of the quartet as in the two-dimensional case (Fig. 4). In this manner a reduction of the spacing in the direction x may result either in an increase of spacing in the direction y, or of that in the direction z, or again in both these directions, all without affecting the orthogonality of the axes.

The Born resultant across the symmetry plane of the pairs is approximated by considering the predominant Born forces only, *i.e.*, those consisting of the forces acting from one particle of a pair to the other and to its four nearest neighbors situated in the symmetry plane of the pair. Thus, the Born resultant across the symmetry plane of particle pair 1-2 along the x-axis in Fig. 7 is approximated by considering the forces between particle 1 and the five others of the configuration. The Born resultant across the symmetry plane of the particle pairs along the other axes presents a slight difficulty as two of the closest neighbors to a particle lie outside the configuration. The difficulty can be resolved in various ways. By sectioning the configuration along a symmetry plane (as P in Fig. 7) and inverting the position of the two halves of the configuration, a new configuration is obtained that is composed of the same particle pairs oriented in the same directions and subjected on the average to the same forces as previously. But now the Born resultant across the symmetry plane of particle pair 3-4 is approximated by considering the forces between either particle and the five others of the modified configuration.

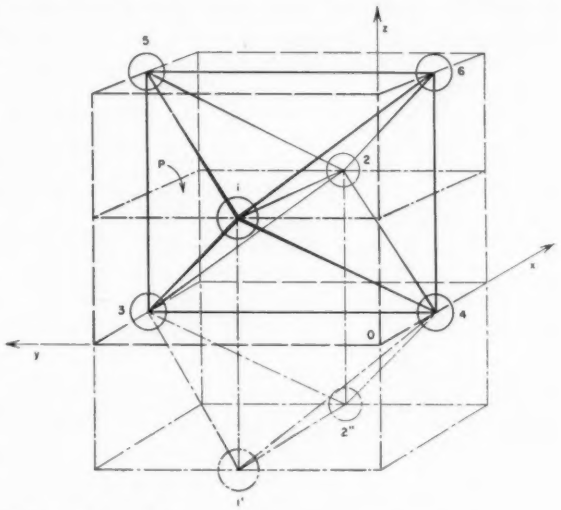

Fig. 7. Diagram of particle sextet.

Under these conditions, let the spacing of the particle pairs and the distance between particles of different pairs be:

$$x \quad y = px \quad z = qx \quad w = rx = \frac{x}{2}\sqrt{p^2 + q^2 + 1}$$

The corresponding Born resultants are then written as:

$$R_x = f(x) + \frac{2}{r} f(rx) \quad ,$$

$$R_y = f(px) + \frac{2p}{r} f(rx) \quad ,$$

$$R_z = f(qx) + \frac{2q}{r} f(rx) \quad ;$$

and the Null resultants are written as:

*The configuration is quite common in any close packing, e.g., the six face-centered particles in the face-centered cubic lattice.

$$N_x = pqx^2\sigma_x \ ,$$
$$N_y = qx^2\sigma_y \ ,$$
$$N_z = px^2\sigma_z \ .$$

Equations (1) and (2), written in three dimensions, now become:

$$R_x - N_x = f(x) + \frac{2}{r} f(rx) - pqx^2\sigma_x = 0 \ , \qquad (3)$$

$$R_y - N_y = f(y) + \frac{2p}{r} f(rx) - qx^2\sigma_y = 0 \ , \qquad (4)$$

$$R_z - N_z = f(z) + \frac{2q}{r} f(rx) - px^2\sigma_z = 0 \ . \qquad (5)$$

VIII EQUILIBRIA OF A SEXTET OF PARTICLES

Equations (3), (4), and (5) determine the Born resultants in terms of the spacings if the principal stresses can be eliminated. To this end, express the principal stresses in terms of their mean:

$$\sigma = \frac{1}{3}(\sigma_x + \sigma_y + \sigma_z)$$

and their deviation therefrom:

$$\sigma_x - \sigma = \sigma_x - \frac{\sigma_x + \sigma_y + \sigma_z}{3} = \frac{\sigma_x - \sigma_y}{3} + \frac{\sigma_x - \sigma_z}{3} \ ,$$

$$\sigma_y - \sigma = \sigma_y - \frac{\sigma_x + \sigma_y + \sigma_z}{3} = \frac{\sigma_y - \sigma_x}{3} + \frac{\sigma_y - \sigma_z}{3} \ ,$$

$$\sigma_z - \sigma = \sigma_z - \frac{\sigma_x + \sigma_y + \sigma_z}{3} = \frac{\sigma_z - \sigma_x}{3} + \frac{\sigma_z - \sigma_y}{3} \ .$$

The deviator component of the stress is then the tensor;

$$\mathrm{T} = \left(\frac{\sigma_x - \sigma_y}{3} + \frac{\sigma_x - \sigma_z}{3}, \ \frac{\sigma_y - \sigma_x}{3} + \frac{\sigma_y - \sigma_z}{3}, \ \frac{\sigma_z - \sigma_x}{3} + \frac{\sigma_z - \sigma_y}{3} \right) .$$

Grouping together the terms independent of σ_x, that is, those representing forces in the x-plane, those in the y-plane, and those in the z-plane, obtains the skew component tensors of the stress:

$$T_x = \left(0 \ , \ \frac{\sigma_y - \sigma_z}{3}, \ \frac{\sigma_z - \sigma_y}{3} \right) = (0, \tau_x, -\tau_x)$$

$$T_y = \left(\frac{\sigma_x - \sigma_z}{3} \ , \ 0 \ , \ \frac{\sigma_z - \sigma_x}{3} \right) = (\tau_y, 0, -\tau_y)$$

$$T_z = \left(\frac{\sigma_x - \sigma_y}{3} \ , \ \frac{\sigma_y - \sigma_x}{3} \ , \ 0 \right) = (\tau_z, -\tau_z, 0) \ .$$

The decomposition of an arbitrary stress into a mean stress component σ and three principal skew components T_x, T_y, and T_z is thus always possible.

In the presence of a skew component T_x only, the Equilibrium Equations (3), (4), and (5) become:

$$f(x) + \frac{2}{r} f(rx) = 0 \ ,$$

$$f(px) + \frac{2p}{r} f(rx) = qx^2\tau_x \ ,$$

$$f(qx) + \frac{2q}{r} f(rx) = -px^2\tau_x \ .$$

Wherefrom, using the equation in Fig. 3:

$$x = \sqrt[6]{\frac{1 + 2/r^{14}}{1 \quad 2/r^8}} =$$

$$\sqrt[6]{\frac{p^2 (1/p^{14} + 2/r^{14}) + q^2 (1/q^{14} + 2/r^{14})}{p^2 (1/p^8 + 2/r^8) + q^2 (1/q^8 + 2/r^8)}}$$

$$y = px$$

$$z = qx,$$

and $$\tau_x = \frac{R_x}{yz} = \frac{R_y}{zx} = \frac{R_z}{xy} =$$

$$12 \frac{p}{q} \left[\frac{(1/p^8 + 2/r^8)}{x^9} - \frac{(1/p^{14} + 2/r^{14})}{x^{15}} \right]$$

The potential energy difference between arbitrary points 1 and 2 is expressed as:

$$E_x = \int_1^2 \tau_x x(zdy - ydz)$$

By defining a differential volume:

$$V_x = \int_1^2 x(zdy - ydz)$$

the energy E_x may be written as:

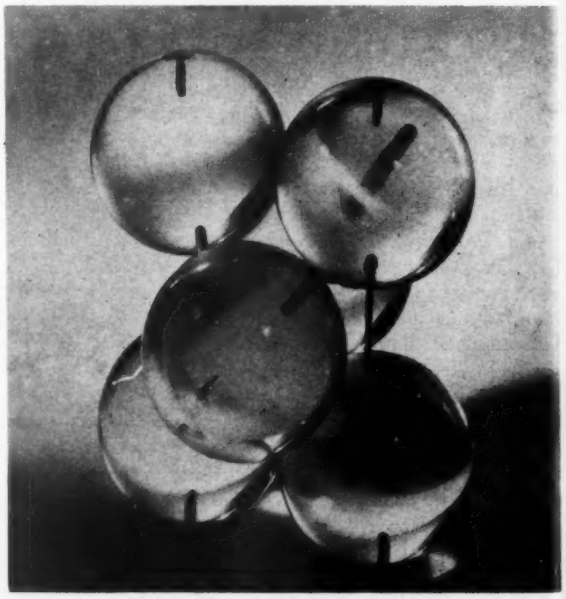

Fig. 8. Configuration A of sextet of spheres. Extended spacing is in the z-direction.

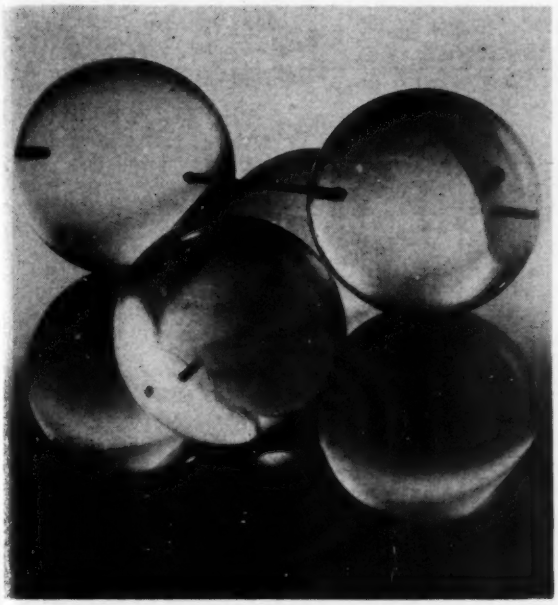

Fig. 9. Configuration A of sextet of spheres. Extended spacing is in the y-direction.

$$E_x = \int_1^2 \tau_x dV_x.$$

V_x measures the amount of deformation suffered by the configuration as y increases while z decreases.

These equations yield two solutions. One of these is associated with configurations that have a contracted spacing in the direction of the x-axis perpendicular to the plane of the skew component T_x, and the other is associated with configurations that have the extended spacing in that direction. Using the orientation of the reference axes shown in Fig. 7, Fig. 8 and 9 show configurations of the first solution, with reference to the orientation of a skew component in the y-z plane. Fig. 10 shows a configuration of the second solution with reference to a skew in the same plane.*

The curves for x, y, z, τ_x, and E_x of the first solution are plotted in Fig. 11 against the differential volume V_x. These curves indicate the presence of free potential wells at A_y and A_z and a reversible free potential barrier at B_x. The presence of a skew stress T_x in a plane orthogonal to the contracted spacing x, i.e., parallel to the extended spacing, raises the height of the barrier in one direction and lowers it in the other. The stressed barrier is then asymmetric. Fig. 8 and 9 illustrate the actual configurations at the free potential wells A_y and A_z.

The curves in Fig. 11 constitute the three dimensional counterpart of those represented in Fig. 5. The curves for x, y, z, τ_x, and E_x of the second solution are plotted in Fig. 12 against the differential volume V_x. Unlike the first solution that describes an open continuous series of configurations, the second solution describes a continuous series that is closed upon itself.

The potential energy curve E_σ indicates the presence of a free potential well at A_x. At this point the configuration is identical to that at A_y or A_z described in Fig. 11 except for a 90° rotation about the z– *or* y–axis. It is hence the configuration illustrated in Fig. 10.

The series of configurations described by this second solution lead from the potential well A_x over a potential minimum at B_y to a potential maximum at D and thence via a second potential minimum B_z to a new potential well that is identical with A_x in all respects except for its abscissa shown in Fig. 12. The fact that the same configuration A_x is represented by points of different abscissae need cause no perplexity. The difference in these abscissae represents the integral of dV_x over a closed path. Since dV_x is not a total differential, its closed integral is in general different from zero.

At points B_y and B_z the configurations are identical to that at point B_x described in Fig. 11 except for a 90° rotation about the y– or z–axis. The configurations B_y and B_z can then be reached via the path described in Fig. 11, but using a skew stress T_y and T_z instead of T_x as illustrated. The free configuration achieves a potential maximum at those points. They also can be reached by the path described in Fig. 12, achieving a potential minimum. The potential configuration about points B_x, B_y, and B_z are therefore potential saddles and constitute the potential barriers separating the potential wells A_x, A_y, and A_z. At point D a maximum of the potential energy is achieved and the spacing in the direction of the three axes becomes identical.

Fig. 12 indicates that any skew component T_x, whether positive or negative, reduces the height of a potential

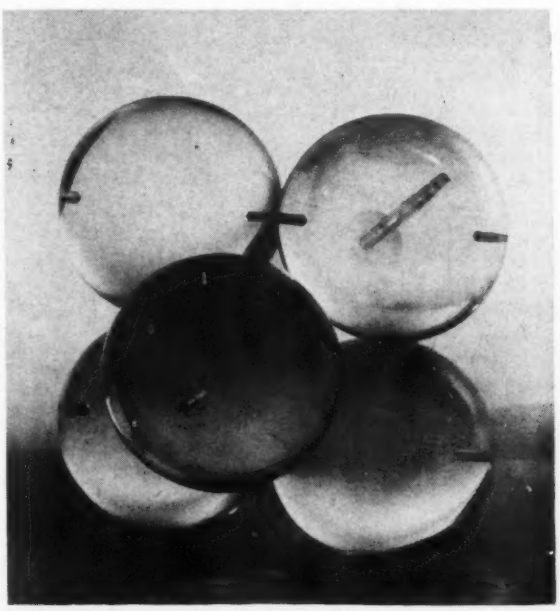

Fig. 10. Configuration A of sextet of spheres. Extended spacing is in the x-direction.

*With the help of the transformation suggested in Fig. 7, it may be noticed that the configuration of Fig. 10, after a rotation of 90° about the y– axis, becomes identical to that of Fig. 8; and, if rotated about the z–axis, to that of Fig. 9. The configurations of Fig. 8 and 9 differ from each other only by a rotation about the x–axis. The algebraic equivalent of these rotations is the cyclic permutation of the subscripts.

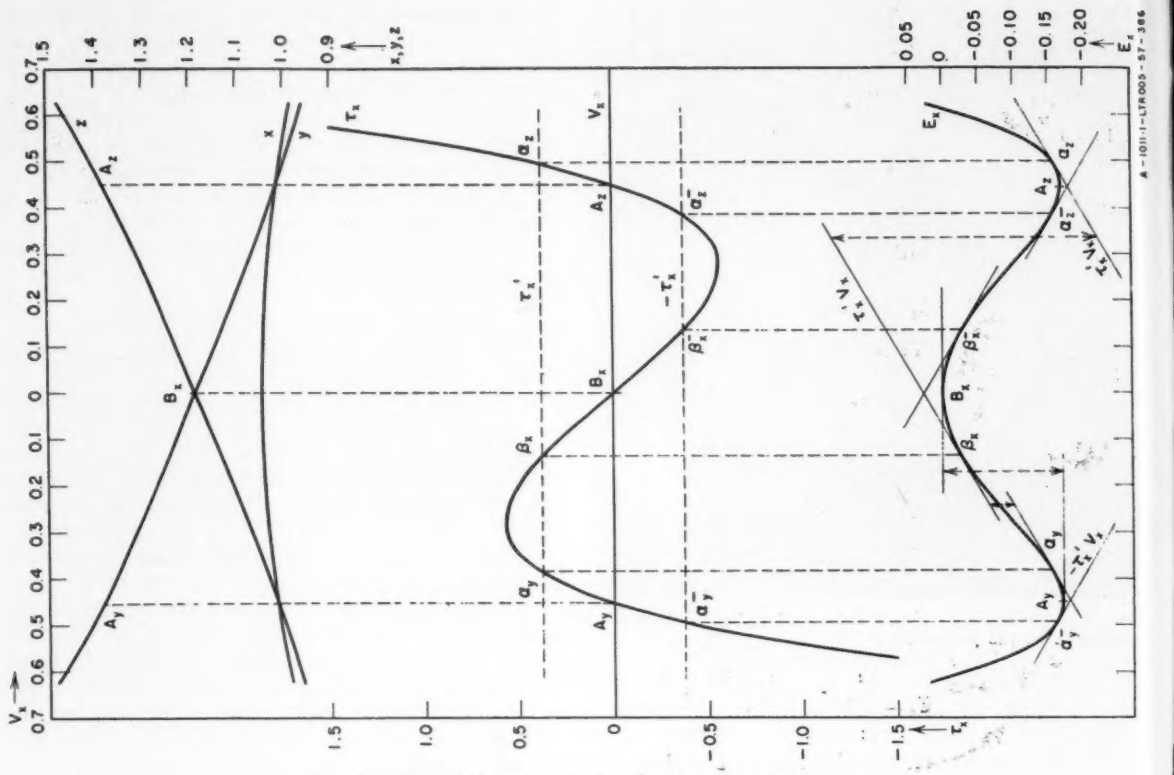

Fig. 11. Equilibria of particle sextet with skew stress $T_x = (0, \tau_x, -\tau_x)$ orthogonal to a contracted spacing.

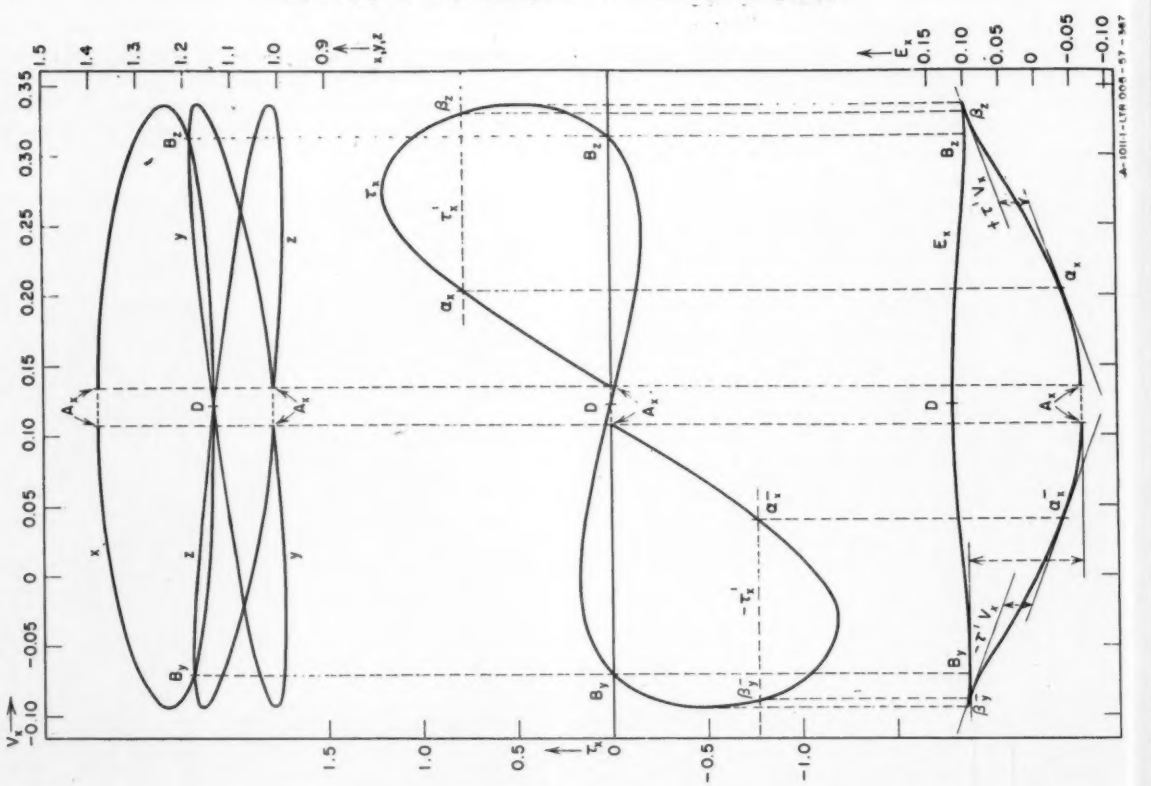

Fig. 12. Equilibria of particle sextet with skew stress $T_x = (0, \tau_x, -\tau_x)$ orthogonal to the extended spacing.

barrier. A positive T_x reduces the height of barrier β_z near B_z, whereas a negative $-T^1{}_x$ reduces that of barrier β_y near B_y. It should be remembered that the sign of a skew stress is simply a matter of convention and does not affect its nature or effect.

It must be noted that the sequence of equilibria with a skew stress T_x plotted in Fig. 11 permits the determination of the heights of the potential barrier near B_x both on the A_y and A_z side. Those plotted in Fig. 12 permit the determination of the height of the other two barriers near B_y and B_z respectively, but on the A_x side only. The exact determination of the height on the other side of these two barriers is a matter of great mathematical difficulty. Considering though, that a skew stress lowers the height of these barriers on the A_x side, a little thought will bring the realization that it must raise their height on the other side by a comparable amount.* In view of the limited importance of this particular change in barrier height, the error introduced by assuming the increase in height on one side to equal the decrease in height on the other, may be disregarded.

In the presence of a skew component T_y or T_z only, the solution is obtained by use of the graphs on Figs. 11 and 12 with cyclic permutation of the subscripts.

In the presence of a mean stress component σ only, Equations (3), (4), and (5) become:

$$f(x) + \frac{2}{r} f(rx) = pqx^2\sigma$$

$$f(px) + \frac{2p}{r} f(rx) = qx^2\sigma$$

$$f(qx) + \frac{2q}{r} f(rx) = px^2\sigma$$

*A more satisfying, but more cumbersome method for the determination of the barrier height on the A_y side of the barrier β_z in equilibrium with T_x consists in neglecting the influence of the fact that dV_x is not a total differential. Then the work performed by the transition from the potential well a_y near A_y in Fig. 11, to the barrier β_z near B_z in Fig. 12 against a skew stress $T_x = (0, \tau'_x, -\tau'_x)$ is independent of the path of the transition. Hence:

$$w]_{a_y}^{\beta_z} = \int_{a_y}^{B_x} (\tau_x - \tau'_x)\, dV_x + \int_{B_x}^{D} (\tau_x - \tau'_x)\, dV_x + \int_{D}^{\beta_z} (\tau_x - \tau'_x)\, dV_x$$

The second integral is transformable, noting that: $dV_x + dV_y + dV_z = 0$, and that τ'_x is constant.

$$\int_{B_x}^{D} (\tau_x - \tau'_x)\, dV_x = \int_{B_x}^{D} \tau_x dV_x + \tau'_x \int_{B_x}^{D} dV_y + \tau'_x \int_{B_x}^{D} dV_z$$

Cyclic permutation of the subscripts gives:

$$\int_{B_x}^{D} (\tau_x - \tau'_x)\, dV_x = \int_{B_x}^{D} \tau_x dV_x + \tau'_x \int_{B_z}^{D} dV_x + \tau'_x \int_{B_y}^{D} dV_x$$

The height of the barrier is then:

Wherefrom, using again the equations of Fig. 3:

$$x = \sqrt[6]{\frac{(1 + 2/r^{14}) - p^2(1/p^{14} + 2/r^{14})}{(1 + 2/r^8) - p^2(1/p^8 + 2/r^8)}} = \sqrt[6]{\frac{(1 + 2/r^{14}) - q^2(1/q^{14} + 2/r^{14})}{(1 + 2/r^8) - q^2(1/q^8 + 2/r^8)}}$$

$$y = px \qquad z = qx$$

$$\sigma = \frac{R_x}{yz} = \frac{R_y}{zx} = \frac{R_z}{xy} = (12/pq)\,[(1 + 2/r^8)/x^9 - (1 + 2/r^{14})/x^{15}]$$

$$E_\sigma = \int_1^2 \sigma(xydz + xzdy + yzdx) = \int_1^2 \sigma\, dV$$

with the volume V:

$$V = \int_1^2 (xydz + xzdy + yzdx) = xyz]^2{}_1 \quad .$$

The equations for x permit the determination of q in terms of p and yield the three solutions:

$$q = 1 \qquad q = p \qquad p = 1$$

or:

$$z = x \qquad z = y \qquad y = x \quad .$$

Furthermore, the equations for x are indeterminate for the common point of the three solutions: $p = q = 1$, *i.e.*, $x = y = z$.

These three solutions are, as a matter of fact, merely different forms of the same solution written for each of the three principal axes.

Consider the form for the x-axis in which $p = q$, or $y = z$. The solution has a branch in which:

$$w]_{a_y}^{\beta_z} = \int_{a_y}^{B_x} (\tau_x - \tau'_x)\, dV_x + \int_{B_x}^{D} \tau_x dV_x + \tau_x' \int_{B_z}^{D} dV_x + \tau'_x \int_{B_y}^{D} dV_x + \int_{D}^{\beta_z} (\tau_x - \tau'_x)\, dV_x$$

Graphically, the first integral is the change in ordinate from the tangent to a_y on the energy curve in Fig. 11, to a parallel to same passing through B_x.

The second integral is the potential difference from the free potential saddle B_x to point D. It is equal to the difference in ordinate from B_y to D on the energy curve in Fig. 12.

The third and fourth integrals are the changes in ordinate of the tangent to β_z on the energy curve in Fig. 12 from the abscissa of B_z to that of D, and from the abscissa of B_y to that of D. These two integrals cancel each other out.

The fifth integral is the change in ordinate from a parallel to the tangent at β_z passing through B_z on the energy curve in Fig. 12, to the tangent itself.

This method gives an increase in barrier height on the A_y side that is somewhat larger than the decrease in barrier height on the A_x side induced by a same T_x. The transition path is possibly not that of least energy.

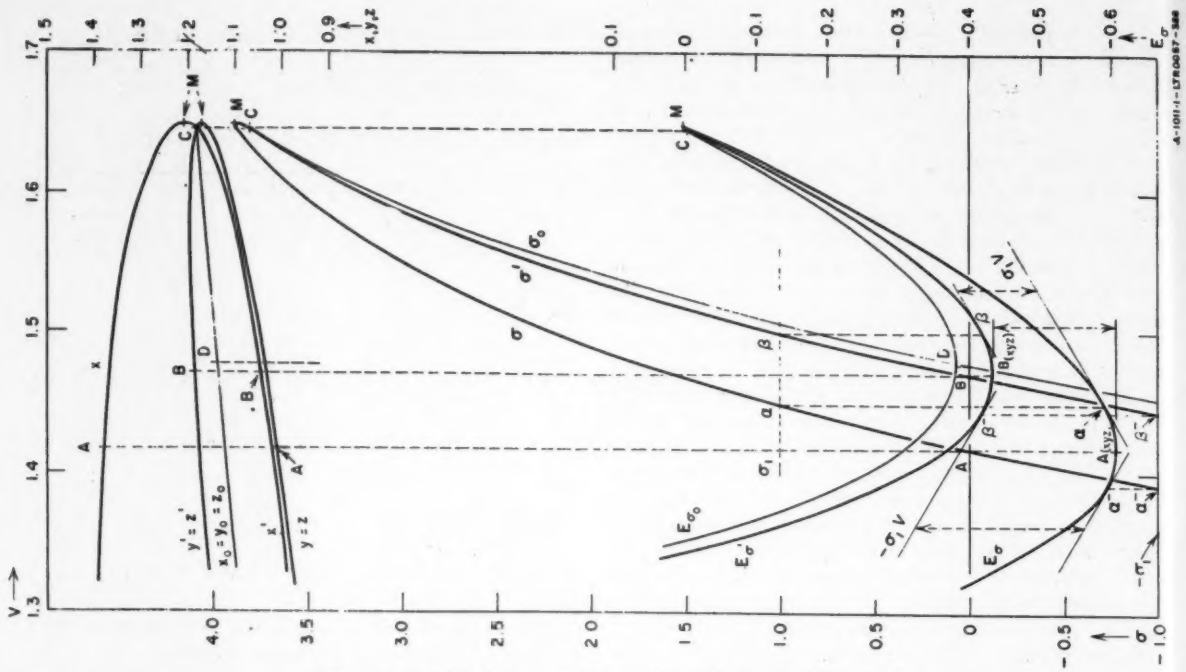

Fig. 13. Equilibria of particle sextet with mean stress τ.

$$x > y = z,$$

separated by the point of indeterminacy at which:

$$x = y = z,$$

from the second branch in which:

$$x < y = z.$$

At the point of indeterminacy itself the equations simplify to:

$$x_0 = y_0 = z_0 = \sqrt[3]{V}$$

$$\sigma_0 = (4/729)\,(16011/V^3 - 34955/V^5)$$

$$E_0 = -(1/729)\,(32022/V^2 - 34955/V^4)$$

and constitutes a third branch of the solution, common to the three forms.

The plots of x, $y = z$, σ, and E_σ belonging to the first branch, of x', $y' = z'$, σ', and E'_σ belonging to the second branch, and of $x_0 = y_0 = z_0$, σ_0, and $E_{\sigma 0}$ belonging to the third branch of the solution, are plotted against the volume V as abscissae in Fig. 13.

These curves constitute the three-dimensional counterpart of those represented in Fig. 6.

The first branch of the solution has a potential well at a point that is readily identified as representing the configuration A_x, wherefrom the potential energy rises to a slight maximum at M_x just before reaching the point of indeterminacy C.

The second branch of the solution has a potential minimum at a point readily indentified as the potential saddle point B_x, wherefrom the potential energy rises monotonically to the point of indeterminacy C.

The third branch of the solution has a potential minimum at a point which is readily identified as representing configuration D of Fig. 12, at which all spacings are equal. From this configuration the potential energy rises monotonically past the point of indeterminacy C.

The points M_x with their counterparts M_y and M_z in the solutions along the y- and z-axes may be pictured as three potential domes symmetrically distributed about the point of indeterminacy C.

The free potential energy configuration about point C may be described as a kind of three-way potential saddle, three of the paths leading from point C over the domes M_x, M_y, and M_z via the first branches with a rising potential, and three of the paths leading from point C to the points B_x, B_y, and B_z via the second branches of the solutions with a falling potential. The potential reaches neither maximum nor minimum at point C.

The free potential energy configuration about point D is a puzzle. This point may be reached from the point of indeterminacy C by the path of the third branch of the solution and attains there a minimum in potential energy. It may also be reached by the paths described in Figure 12 from points B_y and B_z and then attains there a maximum in potential energy. The free potential energy configuration about point D is possibly best visualized as a potential post hole at the point of indeterminacy with potential drainage tunnels burrowing under the potential domes M_x, M_y, and M_z.

Fig. 13 shows further that a positive mean stress σ (i.e., hydrodynamic tension) decreases the height of the barriers between the potential wells slightly, whereas a negative mean stress increases them somewhat. All these barriers remain symmetrical.

IX RECAPITULATION

Because Fracture and Flow are rate processes, it has become necessary to determine the heights of the potential barriers that are overcome during their progress. To this end a method has been developed that determines the equilibria of neutral particles in a body subjected to stresses. Two possibilities must be distinguished: either the tendency of neighboring particles to insert them-

selves between vibrating particle pairs is of no consequence, or it is of material consequence. In the first case only single particle pairs oriented with the most positive principal stress need be considered. In the second case it is necessary to consider sextets of particles composed of pairs that are oriented with the three principal stresses.

The method consists in using the graphs of Fig. 3 in the first case, and of Figs. 11, 12, and 13 in the second. In these graphs the influence of the prevailing stress components is determined in terms of nondimensional stresses that must first be correlated with the usual dimensional stresses. To this end it is necessary to make use of the concepts of elastic moduli that relate the stresses to the strains suffered by their imposition.

The elastic moduli may be calculated from the equations of elasticity*

$$\Sigma_i = \frac{1}{E}\sigma_i - \frac{v}{E}(\sigma_j + \sigma_k)$$

in which:

Σ_i is a principal strain
σ_i is a principal stress
v is Poisson's ratio

and:

i, j, k, stand for x, y, z; y, z, x; and z, x, y, in succession.

In the first case σ_j and σ_k play no role, hence may be assumed nil, *i.e.*,

$$\sigma_j = \sigma_k = 0$$

hence:

$$\frac{\sigma_i}{\Sigma_i} = E \quad .$$

In Fig. 3 the spacing S at the free equilibrium A is unity, the stress or R being nil at that point. At a nearby equilibrium, let the spacing be S' and the stress be R'. The strain Σ is given as the ratio of the change in spacing, to the spacing at the free equilibrium:

$$\Sigma = \frac{S' - S}{S} = S' - 1$$

and Young's modulus for the particle pair is obtained immediately:

$$E = \frac{R'}{S' - 1} = 72.000 \quad .$$

In the second case the rigidity modulus G for the skew stress is obtained from the elasticity equations by subtraction:

$$\frac{\sigma_i - \sigma_j}{\Sigma_i - \Sigma_j} = \frac{E}{1 + v} = G \quad .$$

In Fig. 11, for instance, let the spacings y and z at the potential well A_y be y' and z', the skew stress being nil. At a nearby equilibrium configuration let them be y'' and z'', the skew stress components being τ_x and $-\tau_x$. The rigidity modulus in nondimensional units is then:

$$G = \frac{\sigma_i - \sigma_j}{\Sigma_i - \Sigma_j} = \frac{2\tau_x}{\dfrac{y'' - y'}{y'} - \dfrac{z'' - z'}{z'}} = 23.018 \quad .$$

The bulk modulus is obtained by addition of the elasticity equations:

$$\frac{\sigma_i + \sigma_j + \sigma_k}{\Sigma_i + \Sigma_j + \Sigma_k} = \frac{E}{1 - 2v} = K \quad .$$

In Fig. 13 let the spacings at potential well A_x be x', y', z', the mean stress being nil. At a nearby equilibrium let them be x'', y'', z'', the mean stress being τ. The bulk modulus in nondimensional units is then:

$$K = \frac{3\sigma}{\dfrac{x'' - x'}{x'} + \dfrac{y'' - y'}{y'} + \dfrac{z'' - z'}{z'}} = 59.195 \quad .$$

The three above moduli express the actual moduli of a real body in nondimensional units. The stresses applied to such a body can then be expressed as fractions of their actual moduli.

The graphical determination of the height of the potential barrier in the first case is immediate, using the graph of Fig. 3. The nondimensional stress determines the points α and β on the R-curve. The difference in ordinate between the tangents to the E-curve at these points obtains the barrier height immediately.

The application of the method to the second case is a little more involved. It requires the following steps:

1. Decomposition of the principal stress tensor (σ_x, σ_y,σ_z) into mean stress σ and skew stress tensors T_x, T_y, T_z.
2. Determination of the heights of both sides of each of the three barriers located near B_x, B_y, and B_z in equilibrium with the skews tensor T_x, using the graphs of Figs. 11 and 12 in the manner described. The change in these barrier heights induced by T_x is readily obtained by simple subtraction.
3. Determination of the changes in these barrier heights induced by the skew tensors T_y and T_z. This is obtained in the same manner as for the tensor T_x, by use of the same graphs with cyclic permutation of all subscripts.
4. Determination of these barrier heights in equilibrium with the mean stress σ in the manner described, using the graph of Fig. 13.

The superposition of the changes in barrier heights obtained in 2 and 3 to the barrier heights found in 4 completes the application of the method to the second case.

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* Timoshenko, *op. cit.*

E. LELL AT BAUSCH & LOMB

Dr. Eberhard Lell, a graduate of the Universities of Stuttgart, Germany and Graz, Austria, is taking charge of the AEC radiation damage project in the glass section of the chemical research laboratories at Bausch & Lomb Optical Company in Rochester, according to N. J. Kreidl, chemical research director of the company.

GHERING HEADS REORGANIZED PRESTON LABORATORIES

Preston Laboratories, Butler, Pa., which for thirty years has operated under the sole proprietorship of Dr. Frank W. Preston, its founder, has become a corporation.

Dr. Leonard G. Ghering, who has been associated with Preston Laboratories for the past twenty years, becomes president of the new corporation and director of research.

Dr. Preston continues with the Laboratories as chairman of the board of directors and as a consultant. Dr. Preston will also continue his independent consultant engineering practice.

Dr. Richard E. Mould has been made vice president and manager of research, Mrs. Jane Preston is secretary-treasurer and R. R. Lehnerd becomes vice president of equipment manufacturing and sales. Miss Lena Trombatt is assistant secretary-treasurer.

L. G. Ghering

R. E. Mould

Henry A. Middleton of Toledo, Ohio, an attorney specializing in the glass industry and a former Ohio Supreme Court judge, is a member of the board of directors.

The corporation has leased five laboratory, office and shop buildings on the hundred acre property in Meridian just outside of Butler, Pa. In addition, the new company has assumed ownership of the equipment, scientific library, patents and similar assets.

The Laboratories under its new corporate setup will continue to conduct research projects into the physical and mechanical properties of glass and expansion into other fields is being considered. The development of test methods and equipment and the manufacture of testing machines will round out the firm's activities.

GLASS TECHNICIANS ELECTS W. H. MANRING VICE PRESIDENT

R. W. Hopkins, president of Glass Technicians, Inc., Hamilton, Ohio, has announced the election of W. H. Manring as vice president of the organization, effective October 15.

Mr. Manring has been associated with the glass industry for many years, having been employed by Ball Brothers Company, Muncie, Indiana from 1941 until 1951, at which time he became associated with The Calumite Company, Hamilton, Ohio, where he still serves in the capacity of chief engineer. Mr. Manring is a native of Muncie, Indiana.

EIGHTEENTH CONFERENCE ON GLASS PROBLEMS

The Eighteenth Conference on Glass Problems will be held at the University of Illinois, Urbana, Illinois, Department of Ceramic Engineering, on Thursday and Friday, December 5 and 6, 1957.

One half day will be devoted to each of the following subjects. Themes of the Conference sessions and speakers contributing to these sessions are as follows:

I. A Comparison of Major Commercial Glass Furnaces. Speakers: Electric furnaces—Allen J. Erickson, Northwestern Glass Company, Seattle, Washington; Unit melters—Aaron K. Lyle, Hartford Empire, Hartford, Connecticut; Side port furnaces—Fred Merritt, Toledo Engineering Company, Toledo, Ohio; End port furnaces—Henry Moore, Metro Glass Company, Jersey City, New Jersey.

II. Instrumentation of Glass Furnaces. Speakers: Flue gas analysis—R. K. Gunsaulus, Bailey Meter Company, Cleveland, Ohio; Paul M. Spatz, Diamond Glass Company, Royersford, Pa.; General instrumentation—Hayden M. Setchel, Owens-Illinois Glass Company, Streator, Illinois; John R. Green, Brown Instrument Company (Minneapolis-Honeywell Regulator Company), Philadelphia, Pa.; Automatic cooling wind control for forehearths—Paul M. Spatz, Diamond Glass Company, Royersford, Pa.

III. Raw Materials. Speakers: Use of Sulfates in glass manufacture—Robert W. Hopkins, The Calumite Company, Hamilton, Ohio; Fluorspar for the glass industry—Robert C. Keaney, St. Laurence Fluorspar, Inc., Pittsburgh, Pa.; Discussion on problems in the screen sizing of raw materials—Speaker and panel.

Any communication relating to the conference should be addressed to F. V. Tooley, Professor of Glass Technology, University of Illinois, 208 Ceramics Bldg., Urbana, Illinois.

A. SILVERMAN CONSULTANT TO FOOTE MINERAL

Dr. Alexander Silverman has been retained as a special consultant to Foote Mineral Company, according to Dr. E. M. Kipp, director of research. Dr. Silverman will advise Foote's Research and Development Department on its program of research into the use of lithium in inorganic chemistry and glass technology.

Dr. Silverman is professor emeritus of the University of Pittsburgh and, until his retirement in 1951, was Head of its Chemistry Department. During his long and distinguished career, he has authored over two hundred technical articles and has been awarded some thirty patents. He has been a consultant on glass since 1908.

• The Yuba Milling Division of Metals Disintegrating Company, Inc. announces the appointment of the E. W. Smith Chemical Co. of La Puente, California as exclusive West Coast distributor of their glass barytes to the glass and ceramic industry. Yuba Milling Division has developed a source of a uniform grade of barytes—high in barium sulphate and low in iron content. Stocks of this product are maintained in their plant at Emeryville, California.

Sensitizing, Super-Sensitizing and Irridizing Compounds

Part I

By SAMUEL WEIN

Quincy, Mass.

• THIS IS A CONTINUATION of a previous survey of the technical and patent literature reviewed by Wein. The present survey deals with those compounds that sensitize glass, ceramics, plastics and other surfaces, a technique used in silvering processes (mirror making). The survey likewise includes those compounds used as "super-sensitizers" to form films of copper, nickel, etc. on glass, plastics, etc. And last but not the least, the survey includes those compounds used in making so called "irridized films".

The survey as outlined presents the compounds in alphabetical order, and where possible, the techniques and some of their properties are included.

The present survey includes only those references to the literature that were not reviewed in the earlier paper.

Now that we have an understanding as to what the present paper is to offer, it is but proper that we have an understanding of what constitutes a sensitizer, a super-sensitizer, and an irridized film.

Sensitizers: Metal salts in aqueous or organic solutions when applied to glass, ceramic, plastic or other surfaces, forms as it does an invisible film, the exact nature of which is not as yet understood. At one time it was thought by the early investigators to form a silicate of tin (reaction product) between the glass surface and the tin compound. This idea was soon dispelled when it was found to sensitize surfaces other than glass and ceramics. It is now thought to be an ionizing or electronic effect. Whatever the fundamental functioning characteristics between the surface of the glass or ceramic, plastic etc. it is important to remember that if the given surface is not "sensitized" the subsequent reaction, i. e; silvering, while it may take place, it might not permit the reduction of the silvering process. Sensitizing the surface will certainly "initiate" or hasten its reaction and give rise to a much better or more homogenous silver film.

Super-Sensitizers: Here we are concerned with the noble metals, usually in the form of an aqueous solution, and used immediately after the sensitizing process has been resorted to. Some investigators (inventors) have added the super-sensitizer (compound) to the metal solution about to be precipitated out of solution, i. e; such as the copper, nickel, etc. obviating the need or step in super-sensitizing. We shall discuss the addition of super-sensitizers as addition agents to the metallizing (film forming) compounds in the review of the specific metal such as, for instance, copper, nickel, etc.

The second form of molecular and invisible film (noble metal) is commonly termed as a "super-sensitizer", and it further enhances the reduction properties of the metals about to be formed on the given surface.

Super-sensitizers make use of the metals belonging to that group termed as the "noble metals" and these you will recall are gold, platinum, palladium, etc.

In some of the processes to be discussed, the more common metals such as nickel, zinc, etc., while they are likewise used in further aiding the reduction of the metal under consideration, they merely serve as "seeding agents" or compounds and like the noble metals they too enhance the effect of reduction.

Irridizing: When glass or other ceramic (vitreous) material is made hot and in contact with a metal salt in the form of a vapor or in the form of an atomized solution (very fine spray), a strongly adherent layer of an oxide of that metal is formed on its surface. This process is commonly termed as "irridizing", because the coatings so formed are frequently irridescent due to the interference of light waves reflected from the extremely thin oxide films deposited.

The application of irridizing glass for the production of beautiful art ware is quite old, and for this purpose salts of tin and iron are employed.

More recently it has been found that irridized films have a sufficiently low electrical resistance at normal temperature to permit their use on high tension electrical insulators for the purpose of spreading the potential gradient on the surfaces of the insulators and thus preventing corona and radio interferences as shown by Littleton.

Irridized films can be made to have a high or a low electrical resistance, merely by the incorporation of other metal salts to, let us say, a tin salt and also by subsequent heat treatment, etc. Such metallic oxide films are finding technical and industrial uses in the arts, and we shall discuss these under a separate sub-title.

Mochel finds that combinations of salts such as tin and cadmium, and cadmium with antimony, as well as antimony and indium will produce coatings (films) having very high resistances. Salts of cadmium alone and of indium alone will produce coatings of relatively low resistances.

The thickness of the irridized film may be gauged by the apparent color of the film caused by interference of light reflected from it. As the thickness of the film increases, its apparent color changes and the order or succession of the colors with increasing thickness is analogous to that of the well known Newton rings de-

scribed by Houstoun, which is as follows:

1st order—white, yellow, red
2nd order—violet, blue, green, yellow, red
3rd order—purple, blue, green, yellow, red
4th order—green, red
5th order—greenish-blue, red
6th order—greenish-blue, pale red
7th order—greenish-blue, reddish-white

Obviously, a film of uniform thickness will appear to be of one color only. A slight non-uniformity in film thickness at its edge will produce sufficient color sequence to identify the order of thickness of the main portion of the film. A long strip of glass may be irridized by directing the sprayed solution forming such films at one end and the various orders of colors will be spread longitudinally and will serve as a convenient comparison. Since red marks the end of each order, this color is preferably employed as the distinguishing mark of the successive orders, and, for present purposes, is assigned a wave length of 6200 Angstroms. Calculation shows that the approximate film thickness in Angstroms for the various orders of red is as follows:

Order	Angstroms
1	775
2	2320
3	3870
4	5420
5	6970

The extreme thinness of the irridized films necessitates an explanation of the manner of expression of their electrical resistance. The common unit of electrical resistivity of any material is the "ohm cm." which is the resistance in ohms between two opposite faces of a cube of the material, each dimension of which is 1 cm. For a square film of material the electrical resistivity therefore becomes the resistance in ohms multiplied by the thickness of the film in centimeters. For convenience, the resistance in ohms of a square film of the third order red is employed as the unit of specific resistance, and in order to avoid confusion it is designated "standard resistance".

Irridized films according to Mochel may be formed by heating the glass to about 500°C and spraying a solution upon this hot glass for a length of time sufficient to produce an irridized film of the desired thickness and the desired electrical resistance. The solutions are usually made up of different proportions between tin chloride 100 grams dissolved in 50 c.c. of water and to this is added 10 c.c. of concentrated hydrochloric acid, to which may be added the desired amount of antimony chloride ($SbCl_5$), and if desired other metal salts may be added thereto. Such a solution is sprayed against the hot glass or ceramic surface between 10 to 20 seconds, which will depend upon several factors including the rate of sprayed solution, concentration of the solution and the desired thickness of the film. The thickness depends upon the desired electrical resistance of the film. For thicknesses up to about 5500 Angstroms, the electrical resistance of a film consisting of oxides of tin and antimony decreases linearly as the thickness increases. The electrical resistance may be measured with an ohmeter during the irridizing process. For this purpose and for subsequent use in the application of electric current (contact) to the film, permanent electrical contacts are provided on the glass plate before irridizing takes place. This is best accomplished by metallizing two opposite edges of the glass plate, preferably by the application of a platinizing solution which is fired into the surface of the glass at elevated temperatures.

(The electrical resistance of a conductor is proportional to the length and inversely proportional to the cross sectional area of the conductor. For a given thickness, the resistance of a film then becomes proportional to the length and inversely proportional to the width of the film, and, if the length also equals the width, the resistance remains constant regardless of the size of the film. The term "ohms per square" is therefore employed as the unit of resistance of the electrically conducting films about to be discussed.)

The effect of antimony upon the electrical resistance of tin irridized films is demonstrated in the graph shown in Fig. 1 wherein the resistance of the 4th order irridized films consisting of oxides of tin and antimony on borosilicate glass is plotted against the weight percentage of antimony oxide (Sb_2O_3) calculated from the compositions of the solutions employed to produce irridized films. Since the change in resistance is very great as compared to the change in antimony contact, the resistance is plotted on a logarithmic scale in order to reduce the size of the graph and to permit a better presentation of the data. It will be noted that the resistance decreases very rapidly with very small additions of antimony oxide (.001 per cent to .5 per cent Sb_2O_3.) and a minimum resistance of about 200 ohms per square when the antimony content is approximately 13 per cent Sb_2O_3. For the production of resistance elements for electric heating devices, the antimony content of the film is preferably equivalent to about 1 per cent to 10 per cent Sb_2O_3.

Applications of Irridized Films: Here follows a short survey of applications where irridized films of glass and ceramics have been applied:

Anti-frosting glass on automobiles and aeroplanes (Linder), space heaters, wall panels, combination lighting and heating units, conducting films for condensers; resistance units as used in electrical, radio and television circuits as in the case of potentiometers, rheostats, grid leaks, etc. The use of irridized films is very important because they have a zero or positive temperature co-efficient of resistance.

Colored films containing higher percentages of antimony may be employed as light filters as for example on window panes, building blocks, etc. Such windows or wall units can thus have a pleasing color and a selective transmission for visible light and at the same time can be made self-defrosting or heat emitting by passing a current through the film.

It is interesting to know that the irridized film when deposited on transparent glass and heated by the passage of a source of E. M. F. will emit more radiant heat from the back, that is through the glass, than from the outer face of the film. This enhances their utility, particularly in cases where it might be desirable to bring the heating unit in contact with food to be cooked, as in the case

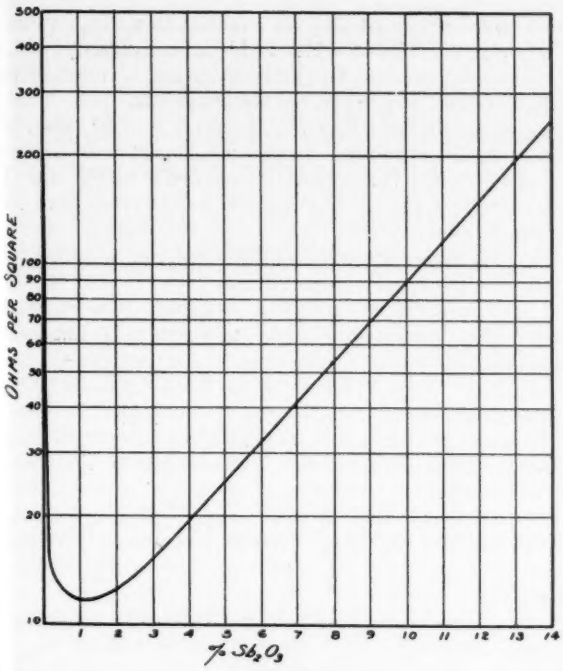


Fig. 1

of griddle cakes, waffles, etc. Other applications in this group are devices for culinary purposes, hot plates, range units, warming tables, baking ovens, grills, toasters, coffee makers, waffle irons, etc; household utensils such as flat irons, serving trays, clothes driers, hair driers, therapeutic heaters, etc.; chicken brooders, low temperature ovens such as paint and lacquer driers.

Now that we have an understanding of the kinds of films to be reviewed, we shall review the chemical compounds that have been mentioned in the literature, and where possible give their properties and general techniques.

This survey is presented in alphabetical order of the chemicals under consideration, and these in turn are reviewed in chronological order. In this fashion we can readily see the gradual development in respect to a given compound and its application.

Aluminum Compounds: During the last World War, aluminum compounds were investigated by mirror makers, electrotypers, etc.; primarily because these were readily available. Bergstrom refers to the use of aluminum compounds as sensitizers, but gives no details for its use, nor does he mention the specific compound.

Aluminum Acetate, Basic: This is offered by Carbide and Carbon Chemicals Company; its chemical formula is Al $(OH)_2CH_3$ COOH. The compound is stabilized with boric acid. It is a fine white powder, readily soluble in hot or cold water, and is slightly hygroscopic. It has been tested by the author and found to have a fair sensitizing effect.

Aluminum Chloride: Littleton mentions this compound, as do Wheeler, McGinnis and Thordarson in their respective patents, but no information is given as to its specific use. A commercial grade is offered by Carbide and Carbon Chemicals Company, stabilized with boric acid. The chemical formula is $AlCl_3$. This compound was tested by the author and it was found to have a fair sensitizing effect.

Aluminum Formoacetate: Its chemical formula is Al $(OH)OOCH_3(OOCH_3)$, available as a fine white powder, slowly soluble in cold water, but is readily soluble in water whose temperature is above 130° F. It is made by Carbide and Carbon Chemicals Company. This compound is different from the basic aluminum acetate in that it contains no boric acid, which latter serves as a stabilizing compound. This compound was evaluated as a sensitizer and likewise found to be fair in its sensitizing effect.

Aluminum Nitrate: Its chemical formula is $Al(NO_3)\cdot 3.9H_2O$. It is a colorless white crystal, referred to by Wheeler, McGinnis and Thordarson as a sensitizer, but with no details given for its use.

Antimony Chloride: Its chemical formula is $SbCl_3$ and it is referred to by Lytle who gives no information as to its use.

Antimony Oxide: Its chemical formula is Sb_2O_3. It is a white crystal and referred to by Cox who likewise gives no details for its use.

Barium Salts: Are referred to by Santomiere as a sensitizing compound, but he does not mention specifically the compound used.

Boron Trichloride: Its chemical formula is $BoCl_3$, and it is available from the Stauffer Chemical Company as a clear fuming liquid, emanating a strong odor of hydrogen chloride. It is corrosive to the skin. It readily decomposes in water to form hydrochloric acid and the hydrates of boron. Because of its corrosive effect on the skin the author was reluctant to test it; however, it is interesting to record here as a possible sensitizer.

Cadmium Compounds: Lytle refers to the use of cadmium salts as a sensitizer, whereas Santomiere mentions its use as a means for forming irridized films. Neither one of the two investigators gives details for its method of application nor refers to the specific compound.

Cadmium Acetate: Its chemical formula is $Cd(CH_3COO_2)2H_2O$. Lytle refers to this compound in connection with his conductive glass. A formulation referred to in his patent consists of:

Cadmium acetate	150 grams
Water	100 c.c.

Cadmium Bromide: This is referred to by Lytle and Junge. Its chemical formula is $CdBr_2$; it is a white to yellowish crystalline needle-like material, readily soluble in water. A typical formula mentioned consists of:

Cadmium bromide	75 grams
Water	100 c.c.

Of this solution take 1 volume (part) and add an equal volume of a 30 percent hydrogen peroxide solution.

Cadmium Nitrate: This compound, containing indium chloride atomized against a borosilicate glass maintained at 700° C. for a sufficient time period to produce films of the first order of thickness, is accredited to Mochel. The measured electrical resistance is about 93 ohms per square, and an irridized indium film of the same thickness has a resistance of about 500 ohms per square. The recommended proportions are:

Example	Per cent $Cd(NO_3)_2$	Per cent In_2O_3	Ohms Per Square
1	98.6	1.4	93

2	97.1	2.9	23
3	94.6	5.4	6
4	89.3	10.7	5
5	85.8	14.2	9
6	81.5	18.5	10
7	78.6	21.4	23
8	76.8	23.2	31
9	74.9	25.1	170

Other formulations Mochel recommends consist of:

Example 1

Cadmium nitrate	10 grams
Indium chloride	0.1 gram
Water	

The first order film was transparent and had an electrical resistance of 650 ohms per square, equivalent to 93 ohms per square for a fourth order film.

Example 2

Cadmium nitrate	10 grams
Indium chloride	0.2 gram
Water	10 c.c.

The first order film was transparent and had an electrical resistance of 160 ohms, equivalent to 23 ohms per square for a fourth order film.

Example 3

Cadmium nitrate	10 grams
Indium chloride	0.4 gram
Water	10 c.c.

The first order film was transparent and had an electrical resistance of 42 ohms per square, equivalent to 6 ohms per square for a fourth order film.

Example 4

Cadmium nitrate	10 grams
Indium chloride	0.8 gram
Water	10 c.c.

The first order film was transparent and had an electrical resistance of 35 ohms per square, which is equivalent to 5 ohms per square for a film of the fourth order film.

Cadmium Oxide: Santomiere and Cox both refer to this compound but give no details for its use.

Calcium Salts: Santomiere refers to calcium salts in his patent, but does not mention which one nor does he give details for its use.

Calcium Carbonate: The chemical formula is $CaCO_3$ and referred to as "chalk" or precipitated limestone. It is a white powder. Miethe rubs the glass surface with cotton wadding which has been dipped into a solution of calcium carbonate mixed with ethyl alcohol and ammonia.

Chromium Compounds: These are referred by Bergstrom in his patent but he gives no details for its use.

Chromium Acetate: Is mentioned by Wheeler, McGinnis and Thordarson who give no details for its use.

Chromic Anhydride: Is referred to by Littleton in his patent but no details are given for its use.

Cobalt Compounds: Santomiere and subsequently Bergstrom refer to cobalt compounds, but neither of them give details for its use nor do they mention a specific compound.

Cobalt Oxide: Cox refers to the use of this compound but gives no details for its use. Its chemical formula is Co_2O_3, available as a blue or black amorphous powder.

Columbium Chloride: This compound is referred to by Littleton; he gives no details for its use.

Copper Acetate: Wheeler, McGinnis and Thordarson mention this compound but give no description of its use.

Gallic Acid: Bassini and Bordini refer to the use of a strong solution of this acid in the order of 5 to 50 per cent concentration.

Germanium Tetrachloride: this is referred to by Gaiser but he gives no details for its use.

Gold Chloride: This is a brownish powder, and is readily soluble in water. Its chemical formula is $AuCl_3HCl.4H_2O$ or $AuCl_3.2H_2O$. It is available from American Platinum Works, J. T. Baker Chemical Company, Davis-K-Products Company, Goldsmith Brothers, Mallinckrodt Chemical Works, Matheson, Coleman & Bell, Merck & Company, Sel-Rex Precious Metals Company, and Technic, Inc.

Smith and Fitzgerald first used a 10 per cent tin chloride solution, rinsed the treated surface, thereafter dipped it in a ½ per cent solution of gold chloride, and again rinsed.

Dr. Myers, who advocated his technique for coppering glass, recommended sensitizing the glass with

Solution 1

Tin chloride	180 grams
Hydrochloric acid (conc.)	180 c.c.
Water	200 mls.

When the milky suspension has settled after half an hour, then filter the solution into a gallon bottle and dilute the filtrate to one gallon with tap water and mix well. Subsequently treat the surface with the super-sensitizer consisting of:

Solution 2

Gold chloride	30 grains
Water	50 mls.

Transfer each 10 milliliters of this 50 ml. to a separate gallon bottle and dilute to a volume of one gallon with tap water. This diluted solution is the super-sensitizer. It slowly decomposes when it stands; it is therefore suggested that only a few days supply be made up at a given time.

The "improved" super-sensitizer used by Dr. Narcus consists of:

Gold chloride (50 per cent)	0.01 to 0.1 gram
Water	1000 c.c.

The solution is operated at room temperature with a two minute immersion time.

The cost of commercial gold chloride (50 per cent metal) is comparable to that of palladium chloride. However, gold chloride is more soluble in water (cold) than palladium chloride. The latter requires hydrochloric acid to give a clear operating solution while gold chloride can be operated with or without the addition of hydrochloric acid. If the acid is preferred, only 1 c.c. need be added per liter of solution. If palladium chloride solutions are without hydrochloric acid, it is necessary to stir the bath thoroughly prior to its use in order to insure best catalyzation of the surface.

(*Continued on page 640*)

Inventions and Inventors

Annealing and Tempering

Burner for Glass Blowing Lathe. Patent No. 2,781,832. Filed August 11, 1953. Issued Feb. 19, 1957. One sheet of drawings; none reproduced. No assignee; by Lawrence T. O'Connor.

The burner arrangement provides an assembly of burner heads offering greater flexibility of adjustment and makes more convenient the desired adjustment of the burner heads for securing uniform application of heat to the work in the desired manner.

The invention provides an assembly of a group of burner heads adapted for heating work mounted in a lathe. The burner heads are arranged for rotation about a vertical axis and they are mutually interconnected whereby motion of one effects mutually similar or symmetrical motion of the other.

There were 3 claims and the following references cited in this patent: 774,456, Smith, Nov. 8, 1904; 1,879,886, Schifferle, Sept. 27, 1932; 2,288,537, Malloy, June 30, 1942; and 2,593,295, Granfield, Apr. 15, 1952.

Feeding and Forming

Casting of Glass Articles. Patent No. 2,778,162. Filed April 12, 1954. Issued Jan. 22, 1957. One sheet of drawings; none reproduced. Assigned to Corning Glass Works by James W. Giffen.

According to the invention the centrifugal casting or "spinning" of tubular glass bodies having perforations through the walls thereof is readily effected by use of a mold having islands on its cavity defining wall surface around which islands the glass can be centrifuged. If the diameter of the article to be cast is such that its mold affords clearance past the aperture forming islands for the deposit of a single molten glass charge of the volume required to form the article the mold may be rotated with its axis vertical. If however, the article to be cast is of such small diameter that charging of the mold with a single gob of glass is impracticable because of the obstructions introduced by the islands thereof, the mold may be charged from a stream of molten glass. Moreover, to facilitate introduction of molten glass in the form of a stream into a mold of small cavity diameter without the glass being intercepted by an aperture forming island, the mold is preferably rotated about its axis while in an inclined plane. By such stream feed method the mold, while rotating at a high speed, intercepts a stream of molten glass at a level above any of its aperture forming islands, and by the combined action of centrifugal force and gravity such glass is then distributed or spun over the entire cavity wall surface and around such islands. The supply of glass to the mold is discontinued shortly before "spinning" of the article has been completed.

The gob feed method differs from the stream feed method only to the extent that it is carried out while the mold is rotating about a vertical axis.

There was only one claim cited in this patent. References were: 1,527,729, Dunajeff, Feb. 24, 1925; 1,751,766, Smith, Mar. 25, 1930; 2,042,015, Moormann, May 26, 1936; 2,667,722, Jenkins, Feb. 2, 1954; and 2,683,332, Litalien et al., July 13, 1954.

Furnaces

Glass Furnace and Method of Heating. Patent No. 2,767,235. Filed December 9, 1954. Issued October 16, 1956. Two sheets of drawings; non reproduced. Assigned to Anchor Hocking Glass Corporation, by Gordon W. Herrold and William H. Fouse.

The present invention relates to glass furnaces and more particularly to one in which gas and electric heating are combined to improve the melting operation and to increase the productive capacity of the furnace.

Electrodes are provided in the sides of the furnace adjacent to the batch end and in the batch end of the furnace. These electrodes are in the cooler portions of the furnace and in the portions where the flow of glass is least and hence the abrasion and wear on the electrodes is at a minimum. The connections to these electrodes establish current paths which produce thermal dams transversely of the flow of the glass to minimize the unmelted glass crossing these thermal dams. The dams are transverse zones across the furnace and across the flow of glass for the purpose of completing the melting operation quickly and uniformly. In addition, the electric current channels are such that the maximum amount of heat is at the middle of the furnace where the flow is the greatest, while the electrodes are located in cooler portions of the molten glass where the flow and abrasive effects are least.

By utilizing the present invention the production of a continuous flow furnace may be increased substantially over that of the usual gas-fired furnaces now in general use and at the same time a higher quality of molten glass will be delivered.

There were 18 claims and the following references cited in this patent: 1,880,591, Wadman, Oct. 4, 1932; 1,944,855, Wadman, June 23, 1934; 2,018,883, Ferguson, Oct. 29, 1935; 2,267,537, Romazotti, Dec. 23, 1941; 2,417,913, Cornelius, Mar. 28, 1947; 2,490,339, De Voe, Dec. 6, 1949; 2,545,619, Lambert, Mar. 20, 1951; and 909,917, France, Jan. 10, 1946.

Glass Compositions

Radiation Colorable Chromium Glass. Patent No. 2,770,922. Filed May 19, 1952. Issued November 20, 1956. No sheets of drawings; none reproduced. Assigned to Pittsburgh Plate Glass Company by John V. Fitzgerald and George S. Bachman.

The present invention is directed to the inclusion of chromium oxide in glasses which are colorable by high energy radiation to increase their resistance to fading which would otherwise be induced by exposure to visible and ultraviolet light.

Ordinary lime-soda-silicate glass turns brown when exposed to X-rays, beta rays, gamma rays, or other comparable high energy radiation. This glass will fade

gradually when exposed to ordinary daylight and will bleach rapidly substantially to its original color when exposed to ultraviolet light. However, if chromium oxide (Cr_2O_3) is added to the glass formulation in a proportion of 0.02 to 2.0 per cent by weight, the resistance to fading is increased.

The glass composition is subject to wide variation and may include by weight between 40 and 80 per cent of SiO_2, about 20 to 60 per cent of alkaline oxide, such as sodium oxide, potassium oxide, barium oxide, calcium oxide, strontium oxide, or combinations thereof, and between 0.02 and 2.0 per cent chromium oxide.

These glasses may be used to measure high energy radiation or glasses may be colored in this manner for use in other devices. For example, in applications where it is desired to provide a single glass member having different light-transmission density in different areas, radiation-colorable, fade-resistant glass may be exposed to high energy radiation to produce uniform coloration of a desired depth. Any desired portions of the glass may then be masked by material that will shield the glass from the high energy radiation and the radiation continued on the exposed portions of the glass to produce therein a deeper coloration. Gradually changing color density can be obtained by gradually moving the mask across the glass during radiation. This process may be used, for example, to make sun glasses having gradually changing light transmissibility across the lens.

The exact amount of Cr_2O_3 to be used will depend upon the glass composition and the resistance to fading that is desired for the particular application. The amount of Cr_2O_3 ordinarly to be used will be between 0.02 and 2.0 per cent by weight.

There were 10 claims and the following references cited in this patent: 1,169,571, Rosenthal, Jan. 25, 1916; 2,515,942, Stookey, July 18, 1950; 2,581,440, Pincus, Jan. 8, 1952; 2,599,349, Ricker, June 3, 1952; 570,946, Great Britain, 1945; and Phillips, *Glass The Miracle Maker* 2nd ed., Pitman Publishing Corp., New York, 1948, p. 43, Example 14.

Glass Wool and Fiber

Glass Fiber Drawing Mechanism. Fig. 1. Patent No. 2,747,335. Filed April 18, 1951. Issued May 29, 1956. One page drawings. Assigned International Harvester Co., by J. F. Courtney and A. C. Radtke.

This invention relates to means for attenuating thermoplastic material and has particular reference to the manufacture of glass fiber strands and the like.

In view of the extremely fast drawing rate and the fragility and low tensile strength of the material involved, considerable difficulty has been encountered in providing a satisfactory drawing mechanism.

The furnace 2 (See Fig. 1) comprises a die plate 4 through which the upstream ends of the filaments 10 are issued in a fan arrangement over the applicator assembly 12 which may be movably supported on a strand 150, directly below the furnace, the filaments then being passed under the gathering sheave 16 which may be journaled at 20 to the frame 150 below the applicator assembly. It will be seen that the strand engages the wheel 22 along substantially 270° and the points of entry of the strand on the wheel 22 and the discharge

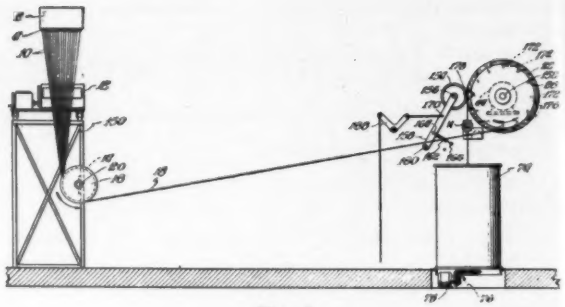


Fig. 1

of the strand with respect to the wheel 22 are laterally and radially separated so that the strand may cross without engagement. The strand 18 is pressed against the wheel 22 by means of an idler roll 154 biased against the strand 18 adjacent to its point of discharge from the wheel 22. As soon as the strand is of desired characteristics the nozzle N is assembled and actuated to provide the tensile force on the strand which is slightly greater than the discharge rate of the strand from the wheel 22 whereby the strand is caused to strip from the wheel and to be snubbed thereagainst. The desired strand is deposited into the container 74, the initial portion being snipped therefrom and discarded.

There were 4 claims and 15 references cited in this patent.

Producing and Treating Fibers. Patent No. 2,763,099. Filed February 7, 1951. Issued Sept. 18, 1956. Three sheets of drawings; none reproduced. Assigned to Owens-Corning Fiberglas Corporation, by Games Slayter, Henry J. Snow, and Samuel D. Philipps.

The present invention embraces apparatus for attenuating mineral fibers by a blowing process.

The molten streams of glass, as they travel through the space between the feeders and the upper surfaces of the blowers are of a temperature well above 800°F, this being the approximate maximum temperature at which moisture will adhere to or be absorbed by a glass surface, so it is apparent that even though the streams are exposed to the atmosphere immediately below the feeders, no moisture will be acquired by the molten streams because of the high temperature.

Such temperatures are well above the vaporization temperature of the oils or lubricants utilized. The presence of the oil vapor in the attenuating zones provides a medium for substantially isolating or protecting the newly formed surfaces of the fibers or glass bodies during attenuation from the atmosphere and from direct contact with the steam from the blasts so that the fibers are coated with a film or layer of liquid lubricant or vapor before they can acquire a coating of moisture.

It is found that fibers formed in this manner are of greater length, a factor which improves the strength characteristics of the mat or assembly of fibers. Furthermore the application of the lubricant to the moisture-free glass surfaces facilitates a uniform distribution of a film of lubricant on each fiber and greatly reduces the amount of lubricant that has heretofore been necessary to coat fibers.

There were six claims and the following references cited in this patent: 2,112,557, Chantler, Mar. 29, 1938;

2,199,087, Drill et al., Apr. 30, 1940; 2,206,059, Slayter, July 2, 1940; 2,315,735, Richardson, Apr. 6, 1943; 2,491,889, Bennett et al., Dec. 20, 1949; and 2,526,775, Slayter et al., Oct. 24, 1950.

Sheet and Plate Glass

Shipping Container for Glass Sheets. Fig. 2. Patent No. 2,734,626. Filed December 30, 1950. Issued February 14, 1956. Three sheets of drawings. Assigned to Libbey-Owens-Ford Glass Company, by Melvin C. Koester and Felix J. Mainz.

The present invention relates broadly to the art of packaging and more particularly to a container, box or carton of novel and improved construction for the handling and shipping of articles, such as bent or curved glass sheets.

Disposed within the carton 15 and positioned on the inner surface of the bottom 16 is a bracing member 26, which serves to cushion the lower marginal edge of the glass sheet A against chipping. The lower bracing member 26 is preferably formed from the same type of material as the carton 15 and is folded along the side edges to form an S-shaped fold 27.

Situated within the carton or box 15 and bracing the concave surface of the sheet A are filler members 28 and 29. These members are also preferably formed from a single sheet of a corrugated material which is turned back upon itself to produce at each end of said sheet two trapezia 30 and 31.

Also positioned within the carton or box 15 and supporting the concave surface of the glass sheet A is the center bracing member 32.

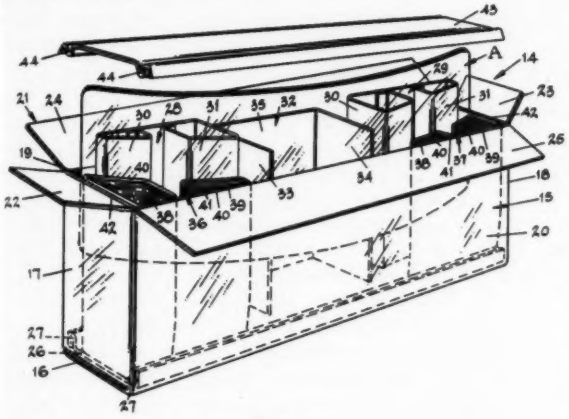


Fig. 2

As thus situated the center bracing member supports the concave surface of the glass sheet at points on both sides of the centerline of the sheet A, at locations recognized as subject to a considerable amount of strain.

Functioning to rigidly position the glass sheet with respect to both the inner walls of the carton 15 and the filler members 28 and 29, and to support the convex surface of said sheet, are end filler members 36 and 37. The relative position of these filler members with respect to the glass sheet A is illustrated in Fig. 2.

There were four claims and the following references were cited in this patent: 1,453,071, Kleeman, Apr. 24, 1923; 1,585,683, Oppenheim, May 25, 1926; 1,713,548, Oppenheim, May 21, 1929; 2,299,355, Stolpman, Oct. 20, 1942; 2,330,348, Elliott, Sept. 28, 1943; 2,337,468, Hilger, Dec. 21, 1943; and 2,609,136, Sider, Sept. 2, 1952.

Pore Closure for Double Glazed Unit. Fig. 3. Patent No. 2,736,143. Filed April 16, 1952. Issued February 28, 1956. One page of drawings. Assigned to Pittsburgh Plate Glass Company by Walter D. Ford.

The present invention relates to double glazed units comprising spaced sheets of glass hermetically sealed together about their edges and it has particular relation to the sealing of pores or vents employed for the equalization of pressures between the inside and outside of the unit during manufacture and for inserting an amount of dry gas in the interior of the unit.

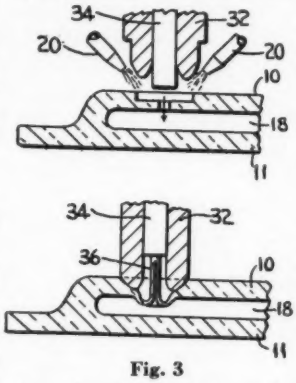


Fig. 3

Glass sheets 10 and 11 (see Fig. 3) are welded together by means of a gas and oxygen flame 20. A graphite tube 32 having a metal wire or tube 34 in the center thereof is pressed or dropped down on the heated areas of the glass surrounding the pore opening. The metal wire or rod 34, which may be a stainless steel wire or rod, is initially heated to a temperature of about 2000°F. in order that it be at a temperature of not lower than 1200°F. at the time of its contact with the heated glass surrounding the pore opening. The heated glass sheet 10 will adhere to the metal rod 34, but not to the graphite tube 32. After the graphite tube and metal rod have been brought into contact with the glass and the glass has adhered to the metal rod 34, the metal rod is withdrawn thereby drawing the glass upward in the graphite tube. The heated glass surrounding the pore opening of sheet 10 adheres to the rod upon its removal and an external glass capillary tube 36 is formed. The tube is formed by drawing out the glass surrounding the pore hole and adhered to the rod a sufficient distance to narrow the diameter of the tube to capillary dimensions. The capillary thus formed is broken from the metal rod to provide an opening into the interior 18 of the unit so that moist gases therein may be purged by means of a dry gas, such as dehumidified air, and the graphite tube is removed.

After purging the interior of the unit, the glass capillary tube 36 is sealed. One method of sealing the capillary tube 36 is to direct a flame at the top of the capillary tube and as the glass melts a small bead is formed at the top of the tube. As the heating is continued the bead moves down the capillary tube to a level which is below the surface of the glass sheet 10. One of the advantages of this type of capillary tube is that it can be easily sealed from the outside of the double glazed unit.

After the capillary tube 36 has been sealed, the depressions in sheet 10 and area around the capillary tube may be filled in to prevent breakage of the capillary tube by appropriate plastics such as rubber latex suspensions,

synthetic rubber such as thiocol, methyl methacrylate polymers, rubber polymers and isomers, vinyl acetal resins such as are employed in safety glass and many other mastic compositions.

There were 5 claims and the following references were cited in this patent: 1,448,351, Kirlin, Mar. 13, 1923; 1,793,039, Yetter, Feb. 17, 1931; 2,000,560, Eitel et al., May 7, 1935; 2,389,360, Guyer et al., Nov. 20, 1945; 2,497,545, Greiner, Feb. 14, 1950; and 2,499,854, Ellefson, Mar. 7, 1950.

Tube and Cane Machines

Manufacture of Glass Tubing. Fig. 4. Patent No. 2,765,586. Filed October 23, 1952. Issued October 9, 1956. One sheet of drawings, one reproduced. Assigned to Corning Glass Works, by Richmond W. Wilson.

The present invention relates to the continuous drawing of glass tubing from a bottom outlet in a container for molten glass.

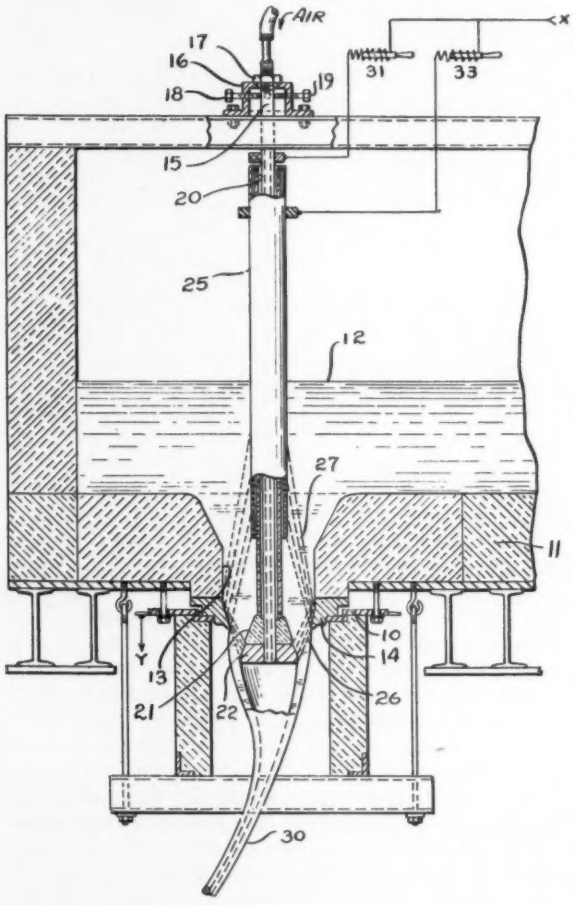


Fig. 4

Tubing 30 may be drawn in the customary fashion (see Fig. 4) from the supply body of glass 12 within the forehearth 11 through the annular space between the ring 14 bordering the bottom outlet 13 and the dielectric and metal bell sections 21 and 22, while bore-maintaining air is supplied to the tubing through the hollow mandrel.

At the same time current is caused to flow from terminal X of such current source through a similar reactor 33 to the sleeve 25 and from the lower end diagonally outward but in a generally lengthwise direction through the tubular stream of glass along paths such as indicated by the interrupted lines 27 to the orifice ring 14 and the terminal Y of such current source.

As will be appreciated, by the employment of the ring 14 as the common terminal of the two current flow paths, sufficient heat can readily be generated in ring 14 to maintain it above the crystallization temperature of the engaged glass as it passes through it. Obviously, since the tool or bells section 22 is entirely encased in glass, the current passing through readily suffices to maintain it well above the crystallization temperature of the glass. Furthermore the heat introduced into the tool may be separately regulated to advantage for control of the wall thickness of the glass tubing being drawn over.

Since the current flow paths are essentially lengthwise of the stream, should "siding" occur, appropriate lateral adjustment of the mandrel can be made and the condition thus corrected without materially modifying the lengths of the described current flow paths through the glass.

There were 4 claims and the following references cited in this patent: 469,454, Rogers, Feb. 23, 1892; 848,422 Wynne, Mar. 26, 1907; 1,975,737, Sanchez-Vello, Oct. 2, 1934; 2,186,718, Ferguson, Jan. 1, 1940; 2,215,982, Slayter et al., Sept. 24, 1940; 2,429,220, Danner, Oct. 21, 1947; and 543,172, Great Britain, Feb. 12, 1942.

W. E. AIKEN, OF L. O. F., DIES

William Earl Aiken, former general sales promotion manager of Libbey-Owens-Ford Glass Company and author of the recent historical book "The Roots Grow Deep," died October 15 in Toledo Hospital after an illness of several months.

Mr. Aiken was born August 29, 1896 in Bowling Green, Ohio, at a time when his father was engaged in oil drilling. Later some of his boyhood years were spent in the oil fields of Oklahoma and Kansas.

He worked as a newspaper man for nearly 20 years in Toledo with the former Toledo News-Bee and later with the Toledo Blade and Detroit Journal and in 1934 joined the U. S. Advertising Corp. For a brief time in 1931 he served as vice president of the Commodore Perry Hotel in Toledo in charge of its convention and publicity department. Having served as account executive for Libby-Owens-Ford while in the advertising agency, it was a natural advance when he became press relations manager of LOF in 1938. In 1947 he was made general sales promotion manager and in 1955 was given the special public relations assignment of preparing a three-volume historical series for Libbey-Owens-Ford, assembling important archives, and doing historical research in the flat glass industry.

Mr. Aiken's first volume, published in May, 1957, entitled "The Roots Grow Deep," covered the story of Capt. John B. Ford and his efforts to establish an American plate glass industry with beginnings in Kentucky, southern Indiana and western Pennsylvania and the development of the former Edward Ford Plate Glass Company in Rossford, opened in 1899.

Surviving is his wife, Dorothy Straub Aiken. The residence is at 3551 River Road, Toledo, Ohio.

The Corrosion of Superstructure Refractories by Batch Materials

• THERE HAS BEEN A MARKED improvement in the quality of tank blocks over recent years so that tank lives have been greatly increased. Furnaces are now often run for two or three years and in some cases for as long as four years. Naturally, this has placed a greater strain on the superstructure refractories, especially as melting temperatures have also tended to rise, and failures are now tending to occur due to superstructure failure.

At the present time silica is used almost exclusively for the super-structure of tank furnaces and improved silica refractories are now available. However, furnaces have been run successfully with alumino-silicate refractories and it is possible that other refractories such as zircon and pure alumina might have applications under specially severe conditions. Of course, long life of the refractory material may not be the only criterion, for the droppings from silica bricks are usually assimilated into the glass, whereas a less soluble material could easily result in stones in the finished ware. A very small amount of refractory can cause very high rejection of ware due to stones, especially in high quality articles such as transmitting valve bulbs or television tube screens.

As very little information was available regarding the attack of refractories by the dust particles from batch, it was decided to carry out laboratory tests and an apparatus was constructed in which it was hoped to simulate the conditions which occur in a tank furnace. This work is reported by T. S. Busby in the December 1956 issue of the *Journal of the Society of Glass Technology*.

The apparatus consisted of a gas-fired furnace in which four specimens could be suspended from a special holder. The furnace temperature was controlled by a thermocouple which, through an electronic controller, actuated two magnetic valves controlling the fuel supply. The temperature could be maintained to ±10°C. The specimens were slowly rotated and glass batch chemicals could be blown on to the specimens by compressed air, through a water-cooled tube. A small Archimedes screw batch-feeder sent a steady flow of material into the air stream. All the tests were carried out at 1400°C. and batch was fed on at a rate of 1 kg. per hour. With some batch materials this test was maintained for 16 hours, but others were found to be so corrosive that the time was reduced to 8 hours.

The experiments so far completed have been concerned with the effect of sodium carbonate, boric oxide, dehydrated borax and soda-lime-silica batch on sixteen refractory materials, two of which were of experimental manufacture and all the rest of normal commercial types.

A summary of the physical properties of the refractories tested is given in Table I, while Table II gives their order of resistance to corrosion for all the tests performed.

It can be seen from the results shown in Table II that a very important factor affecting the extent of corrosion was the chemical relationship between the batch constituent and the refractory. The permeability and porosity of the specimens were also very important in the alumino-silicate materials. The results obtained allow the following conclusions to be drawn:

(1) Boric oxide is much less corrosive than either sodium carbonate or borax.

(2) Silica is very badly attacked by sodium carbonate, borax, and a soda-lime glass batch, but is not severely corroded by boric oxide. It was significant that the lower porosity materials were very much less corroded than the materials of higher porosity.

(3) The zircon refractory was almost unaffected by boric oxide vapor, but it was badly attacked by sodium

Table I
Chemical and Physical Properties of the Refractories Tested

Material	Per Cent Chemical Composition	Per Cent Apparent Porosity	Permeability $\times 10^4$ C.G.S.	Creep in mm./mm./hr $\times 10^4$ at 1400°C
Silica 1	95 S_1O_2	24.5	2900	Nil
" 2	94 "	29.0	1180	0.07
" 3	95 " Low Al_2O_3	20.3	700	Nil
" 4	97 " Low Al_2O_3	20.6	440	"
Alumino-silicate 1	42 Al_2O_3	24.9	1800	22.4
" " 2	44 "	15.1	450	2.2
" " 3	50 "	10.8	28	0.18
" " 4	52 "	26.5	540	10.74
" " 5	60 "	24.7	350	243
" " 6	60 "	23.2	700	0.88
" " 7	72 "	20.3	110	1.50
" " 8	72 "	24.4	450	0.53
Alumina	98 "	24.6	1120	Nil
Zirconia mullite	32 Z_rO_2	2.4	2.4	"
Zircon	99 $Z_rO_2S_1O_2$	24.5	200	336
Fusion cast	32 Z_rO_2, 56 Al_2O_3	2.2	2.6	0.11

Table II

Order of resistance to corrosion at 1400°C, of 16 refractories when sprayed with boric acid, soda ash, dehydrated borax, and a soda-lime glass batch at the rate of 1 kg. per hour. Higher positions in the various columns correspond with higher corrosion resistance.

Boric Oxide for 16 hours	Sodium Carbonate for 8 hours	Dehydrated Borax for 8 hours	Soda Glass Batch for 16 hours
Zircon	Fusion cast	Zirconia mullite	Zirconia mullite
Silica 3	Alumina	Fusion cast	Fusion cast
Zirconia mullite	Alumino-silicate 8	Zircon	Alumino-silicate 3
Alumino-silicate 3	Zirconia mullite	Alumino-silicate 3	" " 7
Silica 4	Alumino-silicate 7	" " 5	Alumina
Fusion cast	" " 3	" " 7	Alumino-silicate 2
Alumino-silicate 2	" " 5	" " 8	" " 5
Silica 1	" " 2	" " 2	" " 1
Alumino-silicate 5	" " 6	Alumina	Silica 3
" " 7	" " 4	Alumino-silicate 6	" 4
Alumina	" " 1	" " 4	Alumino-silicate 6
Alumino-silicate 8	Zircon	Silica 4	" " 4
Silica 2	Silica 3	Alumino-silicate 1	" " 8
Alumino-silicate 6	" 4	Silica 3	Zircon
Alumino-silicate 4	" 1	" 1	Silica 1
	" 2	" 2	" 2

carbonate and a soda-lime glass batch, though less seriously attacked by borax.

(4) The alumino-silicate refractories almost always occupied intermediate positions in respect of severity of attack, and except in the case of sodium carbonate, the alumina content was not the most important factor. When the permeability is plotted against the order of corrosion after spraying with borax it can be seen that there is a linear relationship between the permeability and the corrosion, irrespective of the alumina content.

(5) Zirconia mullite and the fusion-cast refractory were both resistant to attack. Except in the case of sodium carbonate, the zirconia mullite gave the better results. While the chemical composition is obviously very important, it should be noted that both these materials have very low permeabilities.

These results have shown that while it is of great importance to select the right refractory for a particular application, there is a need to improve the quality of superstructure refractories. The small number of tests carried out here suggest that considerably improved refractories are possible. Material of low porosity and permeability is much more resistant to attack than similar material of higher permeability, and silica bricks of lower porosity are now available. It is suggested that manufacturers of mullite-type bricks should now pay more attention to the production of bricks of low permeability rather than those of a more open texture; their outlook in the past has probably been influenced too much by the ability of bricks to withstand thermal shock, whereas in fact, if proper care is taken in bringing a furnace to temperature, thermal shock need not be an important factor. It is also evident that there is a need for newer materials such as the zirconia mullite, for positions where very severe corrosion occurs.

While the more severe conditions of present-day furnace operation have placed a greater strain on the superstructure refractories, there seems to be no reason why further improvements should not be made, and satisfactory furnace life obtained.

AMERICAN WINDOW GLASS INCREASES PRODUCTION

American Window Glass has begun production of window glass in its new glass furnace at Jeannette, according to Otto G. Schwenk, president of the company.

This new unit will give the company a total of five clear glass furnaces of which four will be in production in addition to its operating gray glass furnace. The newest furnace has a rated daily capacity of 85 tons and is served by three 100-inch drawing machines. It was completed early this year, but put on standby awaiting an upturn in demand, Mr. Schwenk said.

With the start of production of the furnace, the second at the company's Jeannette plant, American's output of clear sheet glass will be increased from an operating rate of 54 per cent up to 65 per cent of clear glass capacity.

About 115 workers will be added to the employment rolls at Jeannette.

At the company's Arnold factory, some employees have been called back to jobs in the cutting, warehouse, and shipping departments. Also, the gray glass tank which was placed in production in October last year and operated for about five months to produce sufficient inventory to support the company's introductory marketing program on this new product, then closed for five months, was recently placed back in production.

D. T. KNIGHT PROMOTED

Dallas T. Knight, a former time study supervisor in the American Window Glass Company's Jeannette Plant, has been appointed process superintendent, it was announced by H. Dean Menoher, vice president, manufacturing.

Mr. Knight has been associated with the company since 1936, working successively in the packing and shipping department, as a foreman in the packing department, supervisor of the order department, and as general foreman and time study supervisor.

Current Statistical Position of Glass

Employment and payrolls: Employment in the glass industry during August, 1957 was as follows: *Flat Glass:* A preliminary figure of 27,300 for August, 1957 indicates an increase of .3 per cent from the adjusted 27,200 reported for July, 1957. *Glass and Glassware, Pressed and Blown:* An increase of 3.3 per cent is shown by the preliminary figure of 82,500 for August, 1957, when compared with the adjusted figure of 79,900 for July, 1957. *Glass Products Made of Purchased Glass:* The preliminary figure of 13,900 for August, 1957 indicates an increase of 1.4 per cent from the previous month's adjusted figure of 13,700.

Payrolls in the glass industry during August, 1957 were as follows: *Flat Glass:* An increase of .5 per cent is shown in the preliminary $13,300,628.80 when compared with July, 1957's adjusted $13,233,051.33. *Glass and Glassware, Pressed and Blown:* An increase of 1.5 per cent is shown in the preliminary $29,802,482.33 reported for August, 1957 when compared with the previous month's adjusted $29,365,252.29. *Glass Products Made of Purchased Glass:* A preliminary figure of $4,232,270.75 was reported for August, 1957. This is an increase of 3.7 per cent when compared with the adjusted figure of $4,082,925.24 for the previous month.

GLASS CONTAINER SHIPMENTS

(All Figures in Gross)

Narrow Neck Containers

	Sept., 1957
Food	1,554,000
Medicinal and Health Supplies	1,153,000
Chemical, Household and Industrial	551,000
Toiletries and Cosmetics	659,000
Beverage, Returnable	259,000
Beverage, Non-Returnable	55,000
Beer, Returnable	35,000
Beer, Non-Returnable	460,000
Liquor	509,000
Wine	323,000
Sub-total (Narrow)	5,594,000

Wide Mouth Containers

Food	*2,688,000
Medicinal and Health Supplies	343,000
Chemical, Household and Industrial	125,000
Toiletries and Cosmetics	133,000
Packers' Tumblers	32,000
Dairy Products	195,000
Sub-total (Wide)	*3,516,000
Total Domestic	9,110,000
Export Shipments	246,000
TOTAL SHIPMENTS	9,356,000

*This figure includes Fruit Jars and Jelly Glasses.

GLASS CONTAINER PRODUCTION AND INVENTORY

(All Figures in Gross)

		Production Sept., 1957	Stocks Sept., 1957
Food, Medicinal and Health Supplies; Chemical, Household and Industrial: Toiletries and Cosmetics	Narrow Neck	4,774,000	6,256,000
	Wide Mouth	*4,439,000	*5,144,000
Beverage, Returnable		402,000	1,621,000
Beverage, Non-Returnable		92,000	237,000
Beer, Returnable		115,000	412,000
Beer, Non-Returnable		683,000	699,000
Liquor		1,025,000	1,397,000
Wine		387,000	545,000
Packers' Tumblers		55,000	114,000
Dairy Products		229,000	263,000
TOTAL		*12,201,000	*16,668,000

*This figure includes Fruit Jars and Jelly Glasses.

Glass container production: Production based on figures released by the Bureau of Census was 12,201,000 gross during September, 1957. This represents a decrease of 13.4 per cent from the previous month's production of 14,090,000 gross. During September, 1956, glass container production was 9,878,000 gross or 23.6 per cent under the September, 1957 figure. At the end of the first nine months of 1957 glass container manufacturers have produced a preliminary total of 111,134,000 gross. This is 4.8 per cent over the 106,036,000 gross produced during the corresponding period in 1956.

Shipments of glass containers during September, 1957 were 9,356,000 gross, or a decrease of 48.5 per cent from August, 1957 shipments which were 18,151,000 gross. Shipments during September, 1956 were 10,403,000 gross or 10 per cent over September, 1957. At the end of the first nine months of 1957 shipments have reached a total of 107,874,000 gross, which is 2.3 per cent over the 105,507,000 gross shipped during the corresponding period last year.

Stocks on hand at the end of September, 1957 were 16,688,000 gross. This is 20.5 per cent higher than the 13,866,000 gross on hand at the end of August, 1957 and 24.9 per cent above the 13,371,000 gross on hand at the end of September, 1956.

Automatic tumbler production: During August, 1957 this production was 4,794,000 dozen; this is a gain of 1.1 per cent against the August, 1956 production which was 4,922,000 dozen.

Shipments billed during August, 1957 fell to 5.102,-000 dozen. This is 7.6 per cent lower than the 5,524,000 dozen shipped during August, 1956. At the end of the twelve months period ending August 31, 1957, shipments have reached a total of 54,681,000 dozen which is 9.2 per cent lower than the 60,212,000 dozen shipped in the previous period.

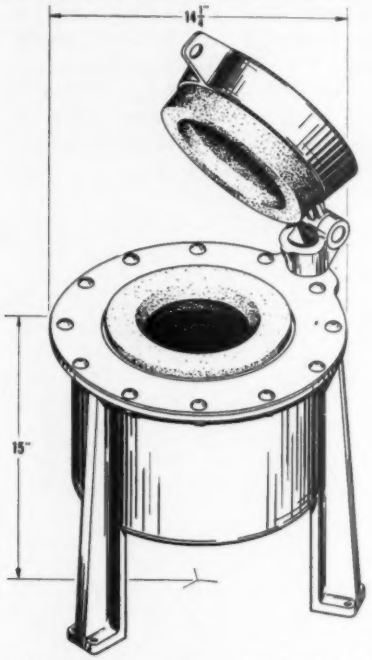
Table, kitchen and household glassware: Manufacturers' sales of machine-made table, kitchen and household glassware during August, 1957 reached 3,402,-000 dozen. This is 8.7 per cent over the 3,130,000 dozen of August, 1956. At the end of the twelve months period ending August 31, 1957, manufacturers had sold a total of 35,513,000 dozen, which was almost identical to the 35,511,000 dozen sold during the previous corresponding period.

New Equipment and Supplies

3200° F. FURNACE BURNS GAS, AIR

Selas Corporation of America, Dresher, Pa., has announced a new low-cost 3200°F. laboratory furnace that operates on any available fuel gas (natural, manufactured, mixed or L-P) and air.

Known as the LAByrinth Furnace, it was designed originally by Selas ceramic engineers for use in their own research work and is now available for general laboratory use. It reaches 3200°F (1760°C) from room temperature in only one hour and is said to



hold that temperature easily with fuel consumption of only 160,000 Btu per hr. (153 cfh natural gas). Charge space is 4½ inches (max.) diameter by 2¾ inches (max.).

Where larger samples must be heated, but lower temperatures are satisfactory, the furnace can be instantaneously transformed by removal of a single element to a 2800°F (1538°C) unit with room for a 4-inch diameter by 5-inch high charge.

Overall size is approximately 14 inches diameter by 19 inches high, including legs for bench mounting. The furnace is also available in a floor-mounted version.

Specially-engineered adaptations of the LAByrinth Furnace principle can be supplied for larger samples or workpieces, and for operation at higher temperatures.

SHUT-OFF VALVE

Homestead Valve Manufacturing Company, Coraopolis, Pa., offers a new quick-acting shut-off valve for air, water, gas or oil service. Known as Figure 202, features of the new valve are said to include positive seating by spring and line pressure, a replaceable resilient disc for positive seal, full opening or closing by ninety degree movement of the handle, and a cam to hold the handle in open position. The vertical or horizontal position of the handle indicates whether the valve is open or closed. Made in ⅜, ½, and ¾ inch sizes, Figure 202 is designed for use on pressures up to 150 lbs. at temperatures up to 250 F.

ELECTRON PROBE MICROANALYZER

Battelle Memorial Institute, 505 King Avenue, Columbus 1, Ohio, has completed and placed in use a new electron probe microanalyzer, said to be a relatively advanced model with unique design features. With this equipment Battelle scientists will be able to isolate for analysis a region less than 1/10,000 of an inch in diameter (2½ microns) on any specimen under study. It can be used in the analysis of all the elements from aluminum through the remainder of the Periodic Table of elements, and is capable of performing chemical analysis on a much finer scale than is possible using conventional procedures.

The analyzer uses electrons from a 50,000-volt tungsten filament to bombard specimens being analyzed. The focused electron beam excites X-radiation of the material being studied, and the X-radiation then passes through a curved crystal vacuum spectrometer. The crystal's position is varied to segregate each element being sought in a specimen.

A Geiger counter, also mounted in the vacuum chamber, detects the wave length passing through the crystal and accurately counts the X-radiation for quantitative and qualitative analysis. An automatic recording device graphically portrays this information as a permanent record of the analysis. A microscope mounted in the microanalyzer permits visual study of the specimen, while it is in the vacuum chamber for analysis. Also included is a specimen translation device incorporated to permit the operator to precisely scan the specimen and "pinpoint" areas of highest and lowest concentration of the element under study.

NEW SPRAY NOZZLE

Spraying Systems Company, 3201 Randolph Street, Bellwood, Ill., announces a new spray nozzle equipped with manually operated shut-off assembly. The nozzle is designed primarily for manifold installations, where selected nozzles must be independently shut off to meet varying spraying requirements. Construction of the nozzle includes a diaphragm valve, shut-off screw and wing nut. To close the nozzle, the shut-off screw is turned down to hold the diaphragm in shut-off position. The wing nut firmly holds the shut-off screw in place. When the shut-off screw is set in open position, the diaphragm valve functions to shut off the nozzle as soon as the manifold line is closed, eliminating any dripping due to reduced line pressure.

These new nozzles are made in brass with internal monel metal strainer and a wide choice of interchangeable orifice tips.

CATALOGS RECEIVED

T. L. Smith Company, Milwaukee 1, Wisconsin has prepared a 12-page booklet describing the company's industrial batch mixers. The booklet contains photographs, drawings, dimensions and specifications of the mixers.

Leeds and Northrup Company, 4934 Stanton Avenue, Philadelphia 44, Pa., has issued Catalog N-33D describing the new high temperature range (7600 F.) of the company's optical pyrometer 8626-C. The new range makes the pyrometer useful in many high-temperature applications. The instrument is also being used in the manufacture of cermets and fiber glass, in research, and in jet engine component tests.

Link-Belt Company, Prudential Plaza, Chicago 1, Ill., has available a new publication, Book 2775, "Geared Flexible Couplings". The 12-page booklet details pertinent application and selection data for couplings with maximum bores ranging up to seven inches and ratings from 2½ to 275 hp per 100 rpm. The company's design of geared flexible couplings provides extra large bore capacity in proportion to outside diameter. It transmits more power, size for size, than other comparable couplings. Housing halves are of forged steel solidly joined by hardened and ground socket head through bolts with lock nuts, arranged for one-tool assembly. Effective quad-ring hub seals retain lubricant and exclude dust, water or other destructive matter.

Book 2775 details four basic applications, each available in ten standard sizes. Write to the company, Dept. PR.

The Chas. Taylor Sons Company, P.O. Box 58, Annex Station, Cincinnati 14, Ohio, has published a new bulletin, No. 322, which discusses Taylor Zircon refractories for the glass industry. The 14-page illustrated bulletin covers the processes and forming methods, properties and application of these refractories. Available from the company at no charge.

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FMC APPOINTS F. A. GILBERT AND F. FARLEY

Frederick A. Gilbert has been named president of the Westvaco Chlor-Alkali Division of Food Machinery and Chemical Corporation, it was announced today by Dr. Carl F. Prutton, executive vice president in charge of FMC's chemical divisions. Mr. Gilbert will continue as president of FMC's Becco Chemical Division.

F. A. Gilbert

F. Farley

Franklin Farley, formerly president of Westvaco Chlor-Alkali Division, will again serve as management consultant to the chemical divisions. In this new assignment, Dr. Prutton pointed out, Mr. Farley will be able to apply his extensive managerial experiences and skill to all FMC's broad chemical interests.

Mr. Gilbert joined the Becco Chemical Division in 1935. He became president of the division in 1956. Early this year he was also made a member of the operating committee for FMC's chemical divisions and moved his headquarters from Buffalo to New York City. Mr. Gilbert is a graduate of Harvard University and Harvard's Advanced Management Program. He is a member of the American Chemical Society, the American Institute of Chemical Engineers, and the Chemical Institute of Canada.

Mr. Farley joined FMC as a management consultant in 1954, after serving for many years as vice-president of the International Minerals and Chemicals Corporation. He is a graduate of the University of Kansas and a member of the American Institute of Chemical Engineers, the American Society of Mechanical Engineers, and the American Association for the Advancement of Science.

NEW OFFICERS AT LINDSAY

Charles R. Lindsay, III, president and chairman of the board of directors of Lindsay Chemical Company, West Chicago, Illinois, has announced the election of the following new officers: Bruce J. Bennett as vice president in charge of production, James S. Murray as vice president, S. Becker Treat as vice president in charge of sales, and Dr. Howard E. Kremers, who succeeds C. W. Stabenau as secretary. Mr. Stabenau retired October first.

Mr. Lindsay also announced that Mark W. Eichelberger who previously served as vice president and treasurer has been promoted to executive vice president and treasurer of the Company.

S. R. SCHOLES WARNS INDUSTRY IN TALK AT ALFRED

The ceramic industry was warned of complacency and the danger of failing to take advantage of new scientific discoveries, in a talk given recently by Dr. Samuel R. Scholes, Professor of Glass Technology Emeritus at Alfred University, at the annual meeting of the New York State Ceramic Association.

Dr. Scholes addressed the meeting which was held at State University of New York College of Ceramics at Alfred University. Nearly 100 leaders from the ceramic industry in the state were in attendance.

With the topic "How Good Is Good Enough," Dr. Scholes maintained that human progress, social or material, continues at a high rate. "But if we chart the curve of betterment with time, for technology in general or for one industry or one plant in particular," he said, "we find no continuous upward climb." He explained that the curve of progress levels off periodically, arriving at certain plateaus where it may remain for many years.

Citing the fact that coasting along on a dead level is pleasant enough, Dr. Sholes admitted that the ugly problem of obsolence does not emerge under these conditions. "The lessons of the past have tremendous value," he said, "but one cannot steer a ship by studying its wake."

A flood of new scientific discoveries are being made daily. Dr. Scholes stated that some of these discoveries are truly significant and are ready to be seized upon for practical advantage.

"The problem of the research man who hopes to benefit industry is the selection of subjects for investigation. The problem of the industrialist is to choose the significant fact as it is disclosed. Thus, he may be sure to leave the plateau of the mediocre, and resume his upward climb to new and better achievement."

HOOKER AND FOOTE EXPLORE HIGH ENERGY FUEL VENTURE

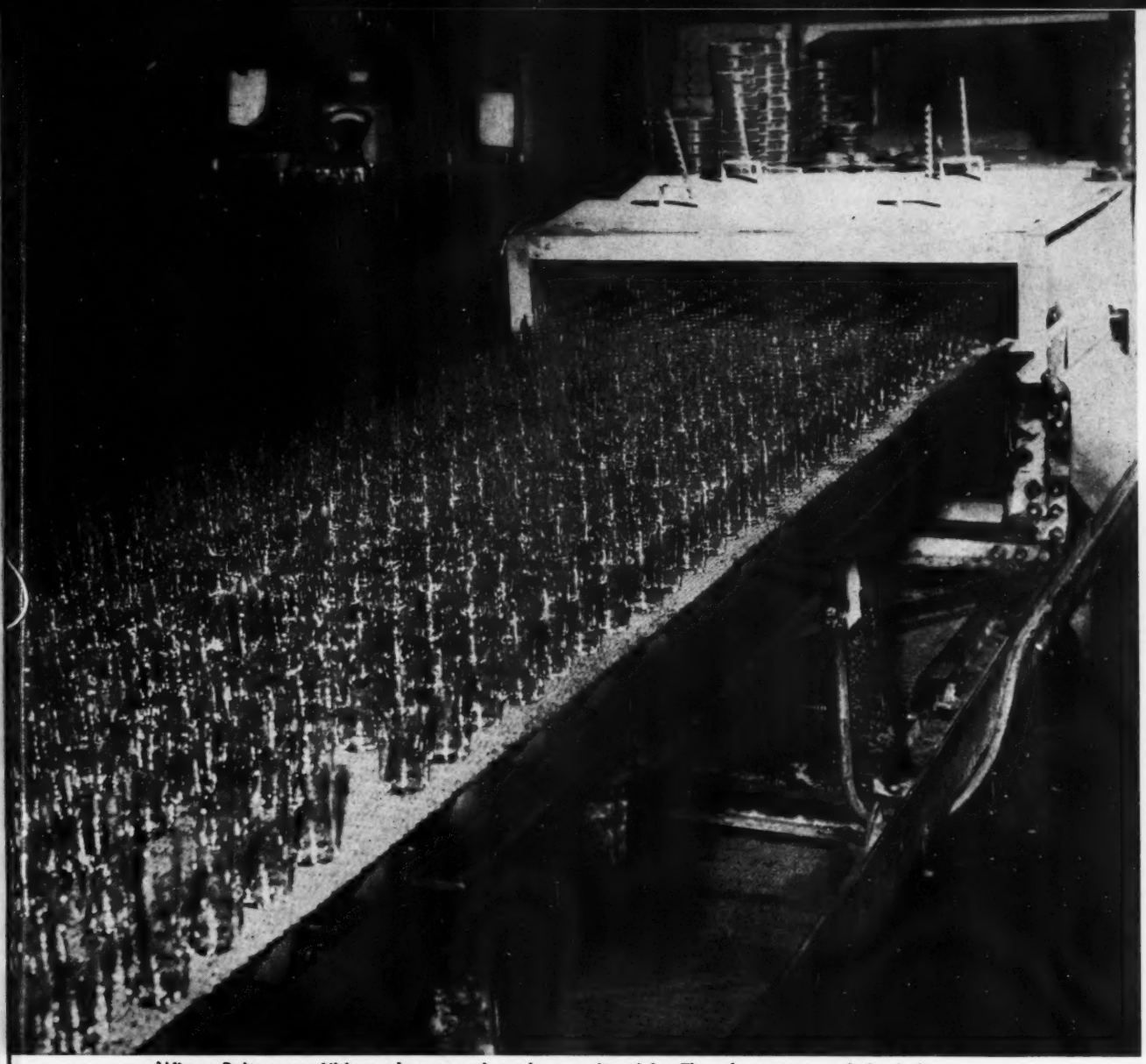
Hooker Electrochemical Company, Niagara Falls, N. Y. and Foote Mineral Company, Philadelphia, Pa., have jointly announced that they are together exploring possibilities for the development, production and sale of components of high energy fuels. Currently, their interests are confined to lithium perchlorate and ammonium perchlorate, materials which act as oxidizers in fuels for rockets and missiles, but studies may be extended to other high energy fuel components later. The joint announcement was made by R. Lindley Murray and Gordon H. Chambers, board chairmen of Hooker and Foote.

CHANGES AT CORNING GLASS

Four organization changes in the New Products Division at Corning Glass Works were recently announced by John B. Ward, Division general manager.

Cyril T. Paquette has been appointed to the newly created position of manager of market evaluation. He will direct long-range product and market development.

Raymond A. Wasson succeeds Mr. Paquette as Division sales manager. Charles L. Schreiber has been appointed manager of product engineering. David A. Sheperd has been named to the new post of manufacturing coordinator.



Wissco Belts carry Libbey glassware through annealing lehr. The glassware—and the belts—are subjected to elevated temperatures for approximately an hour. This is another example of how...

FAMOUS NAMES

ride on WISSCO BELTS

Libbey Glass Division of Owens-Illinois

Libbey is a name that's well known for glassware of top quality. For its annealing operation, which helps insure this quality, Libbey purchased four Wissco Belts of thin, flat construction with improved lehr edge. High heat is applied at the beginning of the operation, and then gradually diminished. The glassware emerges at the cool end of the lehr with stresses and strains equalized. Wissco Alloy Processing Belts are the choice of many famous names in industry—leaders in their fields. You, too, will find Wissco the most economical and efficient belt for every processing operation—for metals, ceramics, glass annealing and decorating.

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2769

Sensitizing . . .

(*Continued from page* 628)

Gold chloride activation gives much less decomposition product than is the case with palladium solutions, assuming some of the solution should enter the electroless bath. Fortunately, an aqueous solution of gold chloride, such as the one described, rinses more easily especially if both a cold and a warm water rinse is used after activation treatment. Hence, the life of the nickel bath is much longer.

Hydroquinone: Loiseleur refers to the use of this compound, but gives no details for its use. Bassini and Bordini refer to the use of strong solutions of this compound, i.e., 5 to 50 per cent concentration.

Indium Salts: Cox refers to the use of indium salts but gives no details for its use.

Indium Chloride: Mochel refers to the use of:

Indium chloride	9.3 gram
Hydrochloric acid	2 c.c.
Water	8 c.c.

Lytle and Junge refer to the use of a saturated solution of this compound in methanol.

Other developments in the use of indium chloride with various proportions of tin chloride dissolved in hydrochloric acid is mentioned by Lytle and Junge. These solutions are sprayed for 10 to 20 seconds on the surface of borosilicate glass previously heated to 700°. The resistances of the film corresponding to the respective solutions expressed in terms of the calculated contents of Indium oxide (InO) and tin oxide (SnO) in the solutions are as follows:

Per cent InO	Per cent SnO	Ohms Per Square
99.1	0.9	10
98.2	1.8	10
96.3	3.7	12
92.6	7.4	16
85.1	14.9	51
76.6	28.4	65
52.0	48.0	286

Mochel uses traces of tin chloride along with cadmium chloride and copper chloride; typical illustrations of such solutions are:

Example 1

Indium chloride	5.3 grams
Tin chloride	0.14 gram
Water	8 c.c.
Hydrochloric acid	2 c.c.

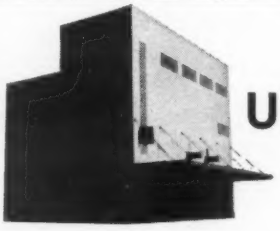
Example 2

Indium chloride	5.08 gram
Tin chloride	0.28 gram
Cadmium chloride	0.11 gram
Water	8 c.c.
Hydrochloric acid	2 c.c.

Example 3

Indium chloride	4.87 gram
Tin chloride	0.56 gram
Copper chloride	0.11 gram
Water	8 c.c.
Hydrochloric acid	2 c.c.

(*Continued on page* 642)

THIS IS THE  ULTRA-MODERN PLANT

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In color research, as in color production, the Drakenfeld technical staff applies scientific thoroughness and the most modern laboratory facilities, and draws on rich field experience to help customers reduce costs and increase product quality. We invite you to learn how our friendly cooperation can serve you. Your inquiry will be answered promptly.

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Milestones in Glass Progress

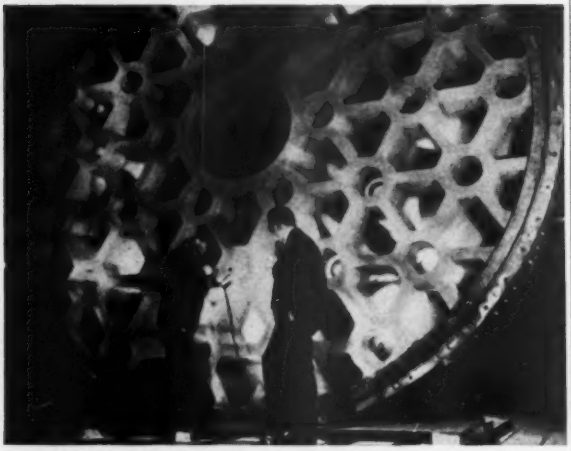
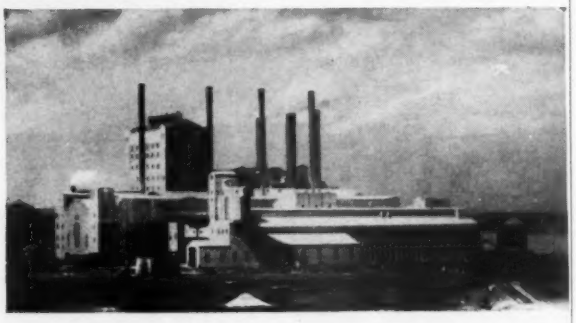


PHOTO COURTESY CORNING GLASS WORKS

1934 The "Mirror of Mt. Palomar" is a 200-inch ribbed disk that allows man to peer six sextillion miles into space! Cast for the Hale Telescope in 1934, it is the largest piece of glass ever made. It demanded infinite care in production, installation; is hollowed out with the incredible accuracy of two millionths of an inch!



1890 Michigan Alkali Company, now a division of Wyandotte Chemicals Corporation, was founded by Captain I. B. Ford to supply Soda Ash to the glass industry; part of Wyandotte's modern Soda Ash facilities is shown above. Wyandotte has literally grown up with glass. Today, as in the past, it is a working partner, supplying technical assistance and raw-material chemicals to those great companies marking milestones in glass progress.

Wyandotte CHEMICALS

Michigan Alkali Division, Wyandotte Chemicals Corporation
Wyandotte, Michigan • Offices in principal cities

Founded by a Glassmaker to Serve the Glass Industry

Sensitizing . . .

(*Continued from page* 640)

Other indium-tin compounds given by these investigators are:

Example 1

The solution consisted of 5.08 grams indium chloride, 0.28 gram tin chloride, 0.21 gram cadmium chloride, 8 c.c. water and 2 c.c. hydrochloric acid, which is equivalent to 93 per cent In_2O_3, 3.5 per cent SnO_2 and 3.5 per cent CdO. The third order film was transparent and had a "standard resistance" of 55 ohms.

Example 2

The solution consisted of 5.08 grams indium chloride, 0.28 gram tin chloride, 0.11 gram cadmium chloride, 8 c.c. water and 2 c.c. hydrochloric acid, which is equivalent to 94.6 per cent In_2O_3, 3.6 per cent SnO_2 and 1.8 per cent CdO. The third order film was transparent and had a "standard resistance" of 30 ohms.

Example 3

The solution consisted of 5.08 grams indium chloride, 0.28 gram tin chloride, 0.11 gram copper chloride, 8 c.c. water and 2 c.c. hydrochloric acid, which is equivalent to 95 per cent In_2O_3, 3.6 per cent SnO_2 and 1.4 per cent CuO. The third order film was transparent and had a "standard resistance" of 133 ohms.

Example 4

The solution consisted of 4.87 grams indium chloride, 0.56 gram tin chloride, 0.11 gram copper chloride, 8 c.c. water and 2 c.c. hydrochloric acid, which is equivalent to 91.3 per cent In_2O_3, 7.3 per cent SnO_2 and 1.4 per cent CuO. The third order film was transparent and had a "standard resistance" of 85 ohms.

Example 5

The solution consisted of 4.45 grams indium chloride, 1.12 gram tin chloride, 0.11 gram copper chloride, 8 c.c. water and 2 c.c. hydrochloric acid, which is equivalent to 83.4 per cent In_2O_3, 15.2 per cent SnO_2 and 1.4 per cent CuO. The third order film was transparent and had a "standard resistance" of 170 ohms.

Example 6

The solution consisted of 5.08 grams indium chloride, 0.28 grams tin chloride, 0.85 grams ferric chloride, 8 c.c. water and 2 c.c. hydrochloric acid, which is equivalent to 89.5 per cent In_2O_3, 3.4 per cent SnO_2 and 7.1 per cent Fe_2O_3. The third order film was transparent and had a "standard resistance" of 47 ohms.

Example 7

The solution consisted of 5.08 grams indium chloride, 0.28 grams tin chloride, 0.053 gram chromic oxide, 8 c.c. water and 2 c.c. hydrochloric acid, which is equivalent to 95.1 per cent In_2O_3, 3.7 per cent SnO_2 and 1.2 per cent Cr_2O_3. The third order film was transparent and had a "standard resistance" of 96 ohms.

Indium Sulfamate: This compound along with triethanolamine is recommended for electroplating purposes by Dyer and Rowan. A casual test by the present author proved it to have sensitizing properties.

Indium Trichloride: Lytle recommends the use of this compound in methanol for irridizing glass.

(*Continued on page* 646)

MORE areas in MORE tanks use MONOFRAX® refractories

FOR FASTER SETTING, plate glass tank uses large MONOFRAX H blocks in breastwalls, port jambs and arches, port neck sidewalls and crowns, regenerator mouth arch assemblies, crown skews, and complete gable wall including doghouse opening arch, relief arch and door shapes. MONOFRAX shapes are shown in blue.

Your choice of refractories for each area of your tank can determine the quality of your glass and the efficiency of your operation. Take this plate glass tank, for example.

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Look into MONOFRAX refractories* to lengthen the life of more areas in your tank, above the glass line and below, and to improve glass quality. For more information just write—

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Why change from Fireclay to Basic Checker Brick?

To make a comparison between fireclay and basic checkers, three questions must be examined:

1. *What are the inherent thermal characteristics of each?*
2. *How does each perform in actual regenerator service?*
3. *How does each affect furnace fuel efficiency?*

1 The two fundamental thermal properties of refractories used as regenerators are heat capacity and heat conductivity. A checker brick must be able to *absorb* large quantities of heat quickly. It must also be able to *release* this heat quickly.

The heat content, or capacity, of a refractory is expressed as the number of B.T.U.'s contained per pound at various temperatures. This value is called "Mean Specific Heat." The heat conductivity of a refractory is expressed as the number of B.T.U.'s per square foot per hour flowing through a 1-inch thick refractory at various temperatures.

Figure 1 shows the average values of these properties for fireclay and basic brick. Basic brick proves superior in both comparisons.

In identical checker settings, however, the basis for comparison of heat capacities should be volume rather than weight (weight is used in the Mean Specific Heats, Figure 1). Thus, when "Mean Specific Heat" values are converted to "Bulk Mean Specific Heat," the advantage offered by basic brick becomes even more apparent (see Figure 2).

Most important, the intrinsic efficiency of a checker brick depends on *successful combination of both* heat capacity and heat conductivity. Figure 3 gives a comparison of these properties expressed as Thermal Efficiency Index. Obviously, basic brick stands far higher in the Thermal Efficiency Index than does fireclay.

NOTE: Factors such as brick shape, size and shape of checkers, type of setting, cycle periods and many others influence performance. Thus, the Thermal Efficiency Index indicates *inherent characteristics* and is not intended as an actual measure of relative efficiency.

TEMP. °F	MEAN SPECIFIC HEATS (Cp) BTU/LB/°F		THERMAL CONDUCTIVITIES (K) BTU/SQ FT/HR/°F/IN	
	FIRECLAY	BASIC	FIRECLAY	BASIC
400°	0.204	0.229	6.5	32.0
600°	0.210	0.238	7.2	28.5
800°	0.218	0.246	7.6	26.0
1000°	0.223	0.253	8.2	23.9
1200°	0.332	0.259	8.8	22.2
1400°	0.341	0.265	9.4	21.3
1600°	0.349	0.271	9.9	20.7
1800°	0.357	0.276	10.5	20.3
2000°	0.366	0.281	11.1	20.0
2200°	0.375	0.285	11.6	19.7
2400°	0.384	0.290	12.2	19.4
2600°	0.392	0.293	12.8	19.1

MEAN SPECIFIC HEATS AND THERMAL CONDUCTIVITIES OF FIRECLAY AND BASIC REFRACTORIES (From International Critical Tables Data)

FIGURE 1

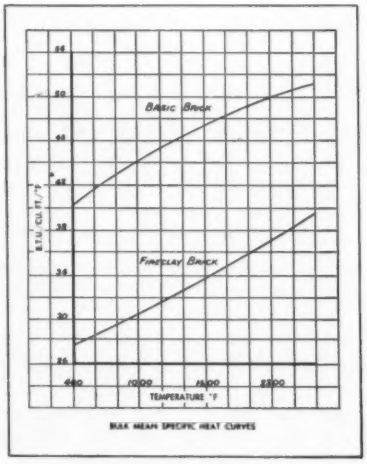

FIGURE 2

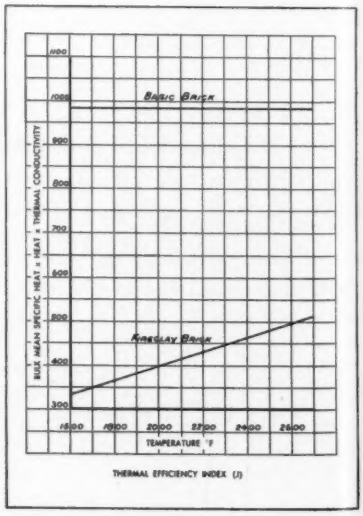

FIGURE 3

2 In a test campaign in the regenerators of a container glass furnace, the top five courses under Number 3 port were set in Kaiser Periclase D basic brick (95% MgO), while an all-fireclay setting was used under Number 4 port.

The campaign continued for 35 months and 3 days. (The furnace was then torn down for non-operational reasons.) At the termination of the campaign the fireclay under Number 4, while still in fair condition, showed considerable accumulations (Figure 4).

In contrast, the basic brick under Number 3 port were still clean and sharp while the fireclay, which started at the sixth course in this area, also showed build-up (Figure 5).

This clogging of clay brick demonstrates the need for going deeper with basic brick in this area. And this—plus similar field observations—also proves that the best results are obtained using basic brick containing the highest possible amount of magnesium oxide with minimum porosity and permeability.

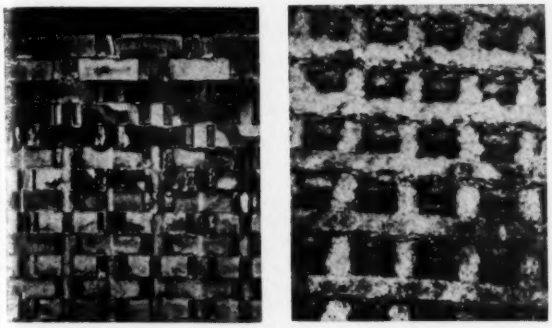

FIGURE 4

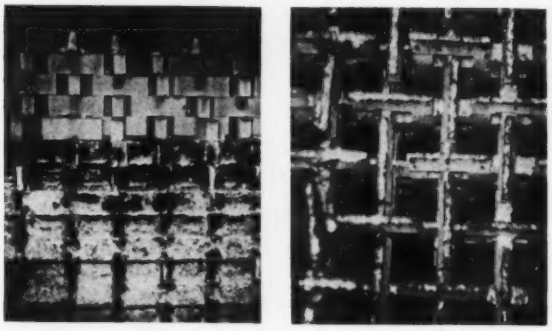

FIGURE 5

3 Since checkers form the regenerative portion of a glass furnace and function mainly for the conservation of fuel, the relative fuel consumption of fireclay versus basic brick is a vital concern.

Here are figures from an actual comparison:

	Campaign "A" Fireclay; token use of basic brick	Campaign "B" Extensive use of basic brick
Life—Operating days	720	1038
Pull—Total tons of glass melted	70,348	109,423
Average tons of glass per operating day	97.8	105.4
Total tons of glass per square foot of melting area during campaign	100.6	156.3
Square feet of melting area per ton per day	7.16	6.64
Average fuel consumption, cubic feet of gas per ton of glass produced	10,967	8662

The fuel consumption in campaign "A" increased from 9342 cubic feet at the start to a high of 11,600 during the latter part (figures from months having same average glass production rates).

In campaign "B," the regenerative cycle was shortened from 20 to 15 minutes to take advantage of the higher thermal efficiency of the basic brick . . . *and gas consumption remained an almost constant 8662 cubic feet throughout the nearly three years of the campaign!*

The plant saved 2305 cubic feet of gas per ton of glass produced as compared to campaign "A"—resulting in a saving of 74.9 cents per ton, or a total saving of $82,000 on fuel over the three-year campaign. Management gives almost full credit to the checker setting.

* * * *

These three discussions illustrate the overwhelming advantages you get with Kaiser Periclase D basic brick in checker settings. These brick, developed specifically for the glass industry, contain over 95 per cent magnesium oxide and offer unusually high density plus high thermal efficiency.

Their high density and absence of impurities provide the properties needed for superior resistance to batch carryover. Installed in chemically-bonded form, Kaiser Periclase D brick becomes ceramically bonded with a tight network of pure Periclase crystals while the furnace is being raised to operating temperature.

Kaiser Periclase D Brick is especially recommended for top courses in checker packings and for port arches and side walls. A second refractory, the silicate-bonded Kaiser Periclase A Brick, is recommended for lower checker courses because of its economy and durability under decreasing temperature and increasing load conditions. These "A" brick have high resistance to carryover, maximum density, low porosity and high hot load strength.

For supporting data on how the superior characteristics of Kaiser Periclase A and D brick can increase the service life of your checkers, write for our booklet, "A Report on a Better Basic Brick for the Glass Industry."

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Call or write Kaiser Chemicals Division, Dept. G71x41, Kaiser Aluminum & Chemical Sales, Inc., at any of the Regional Offices listed below:
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HAMMOND, IND. . . . . 518 Calumet Building
OAKLAND 12, CALIF. . . . . 1924 Broadway

Sensitizing . . .

(*Continued from page* 642)

Iridium Salts: Bergstrom refers to this as a super-sensitizing agent, but gives no details for its use.

Iron Compounds: Santomiere and Wheeler, McGinnis and Thordarson, including Bergstrom refer to the use of iron salts but they do not mention the specific compound.

Iron Chloride: Better known as ferric chloride, its chemical formula is $FeCl_3$, available as a brownish-yellow powder or lumps, readily soluble in water.

Wheeler and McGinnis suggest the use of:

Iron chloride	80 grams
Hydrochloric acid	10 c.c.
Water	90 c.c.

Subsequently Wheeler, McGinnis and Thordarson spray iron chloride solutions on the previously heated glass or ceramic surface (at 200°F.). In a modified formulation they mix tin chloride with the iron chloride.

Littleton sprays surfaces with iron chloride solutions emanating from a heated Erlenmeyer flask provided with a delivery tube and directed to the given surface. The surface in this case was heated to between 600° to 750°C.

(*To Be Continued*)

NEW ASSIGNMENTS AT DIAMOND ALKALI

Election of four key executives of Diamond Alkali Company, Cleveland, Ohio, to new management assignments was announced at the firm's national headquarters by Raymond F. Evans, chairman and chief executive officer, following action by the board of directors.

A. H. Ingley, vice president, manufacturing for the past nine years and a director of Diamond since April, now becomes senior vice president, a newly-created position.

James A. Hughes, treasurer of the company since mid-1955, is now advanced to vice president, administration, also a new post in the Diamond organization.

Donald S. Carmichael, secretary for ten years, is named to the additional post of general counsel.

R. H. Armor, assistant treasurer since 1953, succeeds Hughes as treasurer.

In making the announcement, Mr. Evans said, "The board's election of Mr. Ingley and Mr. Hughes to their respective new posts is expected to result in more effective coordination of our corporate policies and programs as well as further streamlining of administrative procedures and methods in the interest of improved profit performance."

L. O. F. NAMES J. C. OGLE, JR. DIVISION GENERAL MANAGER

James C. Ogle, Jr., a career man associated with the Liberty Mirror division of Libbey-Owens-Ford Glass Company for 22 years, has been named division general manager succeeding William H. Colbert, for several years president of the division.

In making the announcement, George P. MacNichol, Jr., president, said that Mr. Colbert will continue in an advisory and consulting capacity with Liberty Mirror division serving on its management policy committee and also will continue as a member of the Libbey-Owens-Ford Technical Policy committee.

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The original optical grade cerium oxide. Also available in mirror grade.

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solves glass problems!

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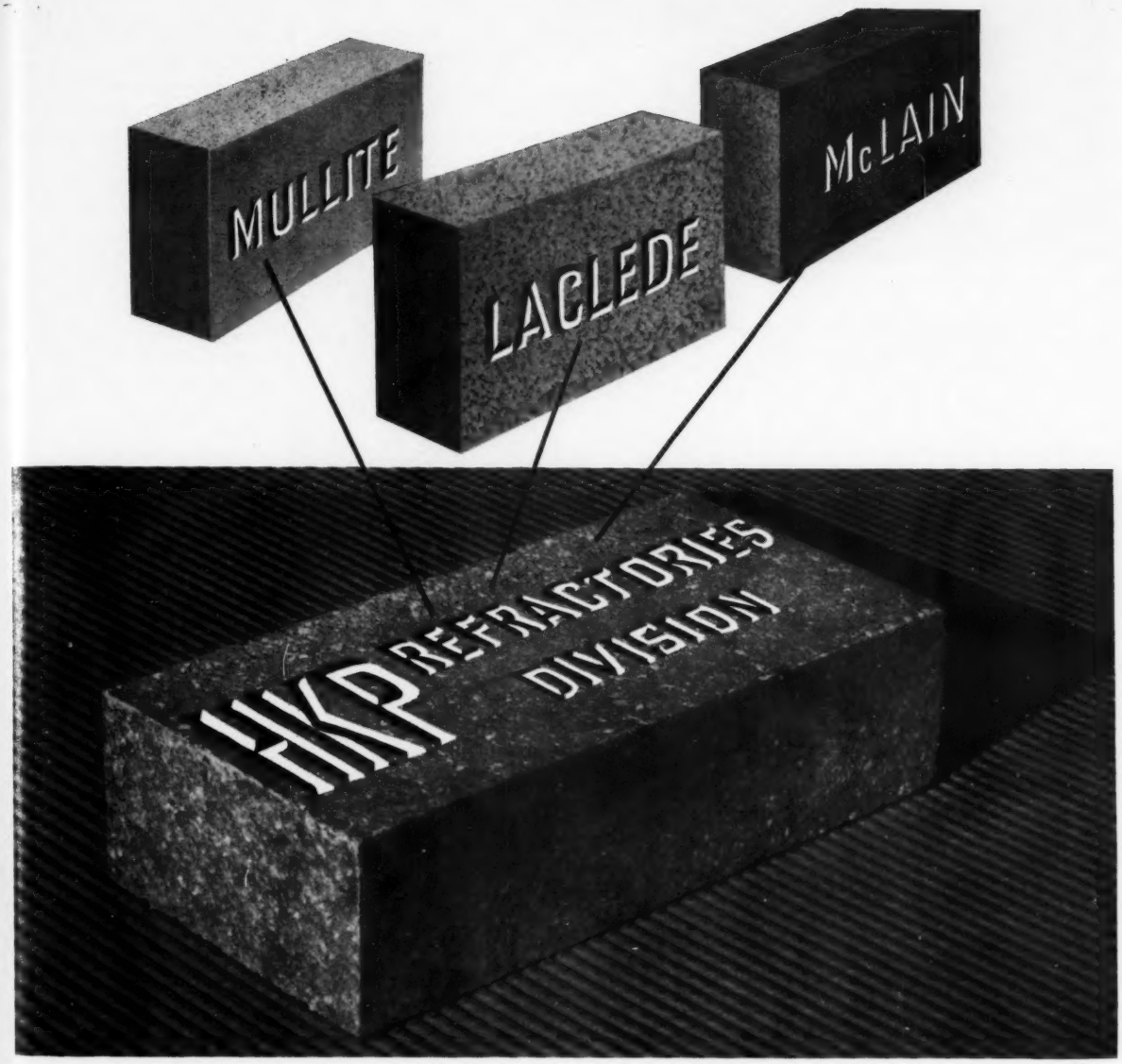
Charles Eisler, Jr.
President



HKP now gives you this newly expanded source of refractories

Now the combined operation of Laclede-Christy, McLain Fire Brick and Mullite Works is under H. K. Porter Company, Inc. leadership. This integrated organization gives you an expanded refractory product line from *one source*. It means increased benefits for you through greater research, manufacturing and distribution facilities. It means still better service to you.

When you need refractories of any type, check HKP Refractories Division, the *growing* producers in the industry.

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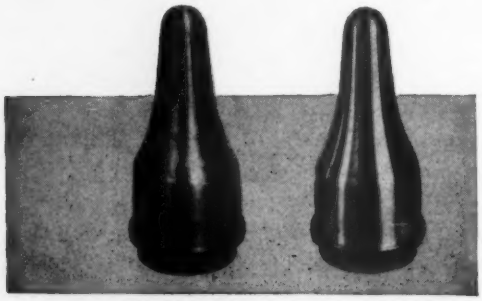
THERMOSPRAY coated mold plungers give 8 times longer service life

Important savings are being made in production down-time and replacement-part costs on equipment subject to heat and abrasion. Typical of these are mold plungers like those shown here which are being THERMOSPRAY coated by glass manufacturers for protection against heat corrosion. Other advantages include improved product quality, with better finish on glass parts. Longer production runs are feasible without dismantling machines.



Before (left) and after (right) coating with METCO *ThermoSpray* Process. Users report coated plungers last average of 8 times longer than uncoated. Parts finish is improved, production down-time reduced.

The new METCO THERMOSPRAY Process consists of spraying specially developed alloys in powder form with the METCO THERMOSPRAY GUN. These alloys are of the nickel-chrome-boron type and are self-fluxing. No compressed air is required. Coating hardnesses range from Rc 30 (machineable) to Rc 65, depending on the specific THERMOSPRAY alloy used; will even outwear hardened steels from 3 to 10 times. Spraying speeds are higher – 8 to 10 lbs. per hour – and deposit efficiency far greater (up to 97%) – than with any other type of available equipment.

Application of these materials in powder form permits close control of the amount applied and leaves a comparatively smooth surface that requires a minimum of finishing compared to other methods of application.

Free bulletin—write today for Bulletin 126 which illustrates and describes the METCO ThermoSpray Process or ask for a call by a full-time, company-trained Metco Field Engineer in your territory.

The following names are the property of Metallizing Engineering Co., Inc.: METCO, ThermoSpray.*

**Reg. U. S. Pat. Off.*

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In Great Britain: Telephone: EDGEWOOD 4-1300
METALLIZING EQUIPMENT COMPANY, LTD.—Chobham near Woking, England

NEUBAUER IS PRESIDENT AT COLUMBIA-SOUTHERN

Election of Joseph A. Neubauer as president of Columbia-Southern Chemical Corporation, a wholly-owned subsidiary of Pittsburgh Plate Glass Company, was recently announced by the company.

J. A. Neubauer

As president of Columbia-Southern Mr. Neubauer succeeds Edwin T. Asplundh who has been elected board chairman of the Pittsburgh Plate Glass Company and Columbia-Southern Chemical Corporation.

A 46-year old chemical engineer, Mr. Neubauer joined Columbia-Southern at its Barberton, Ohio, plant soon after his graduation from Case Institute of Technology in 1932. At Barberton he served as chemical engineer in the process department, development engineer and as assistant production superintendent.

When Columbia-Southern decided in 1941 to build a large chlorine plant at Natrium, W. Va., Mr. Neubauer was assigned as chemical engineer. When the plant was completed in 1943, he remained as plant manager.

He was assigned to the Pittsburgh, Pa., headquarters in 1946 as technical advisor to the vice president and three years later was named technical director for the company. In 1955, he was elected vice president and technical director and a member of the board of directors of Columbia-Southern.

BLUE RIDGE INTRODUCES FLAT BOROSILICATE GLASS

A flat borosilicate glass, featuring high resistance to thermal shock and chemical action, is being introduced nationally by Blue Ridge Glass Corporation of Kingsport, Tennessee.

"The new borosilicate product can be used continuously under proper conditions at temperatures approaching 900 degrees Fahrenheit," reports Richard W. Rigg, Vice President—Marketing.

"However, when it is used for sight glasses, the temperature differential between the faces usually sets the maximum operating temperature at about 450 degrees Fahrenheit, which temperature is seldom exceeded in most industrial operations."

Allowable face temperature differentials, as shown by tests on 6x6-inch plates, are: one-eighth inch thick—180 degrees C.; one-fourth inch thick—150 degrees C.; and, one-half inch thick—100 degrees C.

• The O. Hommel Co., Pittsburgh, Pa., announces that Lyle H. Slack of Whitesville, N. Y., has been selected as recipient of the O. Hommel Senior Fellowship at the College of Ceramics, State University of New York, at Alfred University for the year 1957-58. Mr. Slack's work will pertain to a specific problem with porcelain enamel.

For Uniform Results start with Diamond Soda Ash

Uniformity in finished glass starts with soda ash of uniform density and grain size. That's why DIAMOND SODA ASH has been the favorite of quality glass makers for more than 40 years. • For product and technical information, call your nearest DIAMOND Sales Office or write DIAMOND ALKALI COMPANY, 300 Union Commerce Building, Cleveland 14, Ohio.

Diamond Chemicals

HARBISON-WALKER BUILDS NEW RESEARCH CENTER

Construction of an integrated modern research center has been started by Harbison-Walker Refractories Company on a 21-acre suburban site south of Pittsburgh. When completed next year, the million dollar project will house all of the company's extensive research activities. Employing approximately 100, the Research Center will provide expanded facilities and staff for the study of highly refractory materials and the development of processes for converting them into industrial products. Ample provision is being made for future expansion.

Earl A. Garber, president, has stated that not only has the company expanded activities into new refractory product fields, such as mullite, silicon carbide and zircon, but that its new facilities in several foreign countries has made available additional raw materials of great promise. While refractories and insulation for industrial furnaces and chemical processing are the company's principal products, Harbison-Walker has diversified into the manufacture of molding media or investment materials for shell molding and precision casting, and into magnesium chemicals. Research will be intensified in the field of refractory monoliths to broaden the numerous markets already established. The use of refractory castables and gunning materials for rocket launching sites and for jet aircraft maintenance areas are closely related to the products used for lining catalytic cracking and reforming units in the oil refineries, in that both services require outstanding resistance to abrasion from fast-moving particles at high temperatures. The company's role in the nuclear energy field will also be explored more fully with the new facilities.

The Research Center, having total floor space of 45,000 square feet, will be comprised of two major structures connected by a reception area—a fine instruments building and a pilot plant building.

D. H. JUPP APPOINTED PILKINGTON PRESIDENT

Donald H. Jupp has been appointed president of Pilkington Brothers (Canada) Limited and Pilkington Glass Limited, succeeding Mr. Lewis J-B. Forbes who retired recently.

Mr. Jupp's appointment was announced by J. F. Moeser, secretary of the company, following a meeting of the board of directors. For the past several years Mr. Jupp has served as executive vice-president.

In his new position, Mr. Jupp will also be chairman of the board of directors of the Edmonton Paint and Glass Company Limited, Edmonton, Alta., and the Scott Paint-Varnish Company Limited, London, Ont.

The new president has been associated with Pilkingtons for 24 years and started at St. Helens, England, as a trainee.

• Organization of Leeds & Northrup, Canada, Ltd., a wholly-owned subsidiary of Leeds & Northrup Co., of Philadelphia, has been announced by I. Melville Stein, Chairman of the Board of the new company and President of its parent organization. The firm is located at 61 Industry St., Toronto 15.

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For elimination of production problems and modernization of methods.

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Outstanding operation for efficiency and top glass quality.

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Straight line production units to bend glass components accurately to curvatures.

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Designed and built with all machinery installed in position.

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Embodying efficient FIROLL Burners and other new features that assure delivery of large output economically.

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Designed, engineered and erected. Gas or oil firing equipment.

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For modernization of existing glass plants.

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Fast, accurate, safe. For various shapes and sizes of containers.

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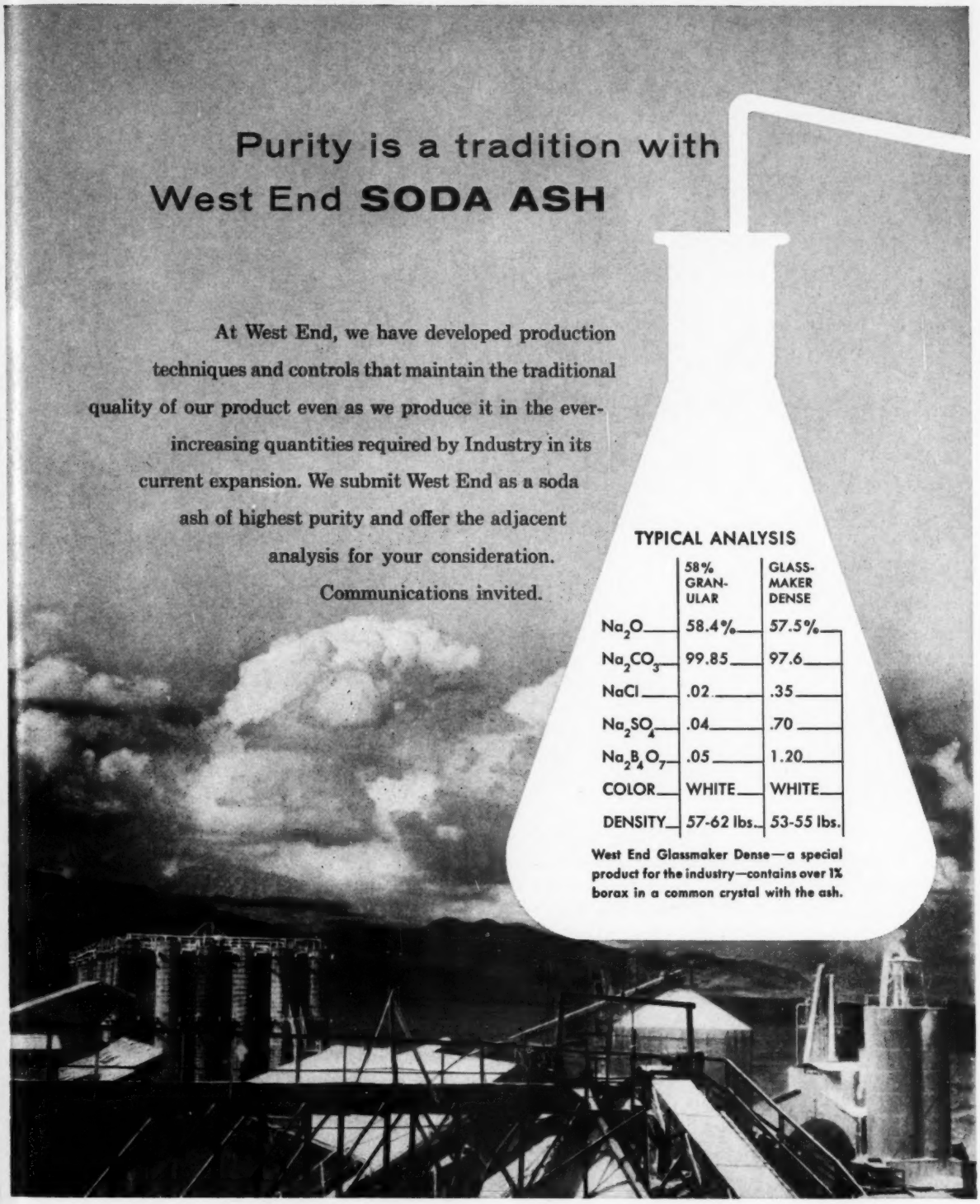
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At West End, we have developed production techniques and controls that maintain the traditional quality of our product even as we produce it in the ever-increasing quantities required by Industry in its current expansion. We submit West End as a soda ash of highest purity and offer the adjacent analysis for your consideration.
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TYPICAL ANALYSIS
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West End Glassmaker Dense—a special product for the industry—contains over 1% borax in a common crystal with the ash.

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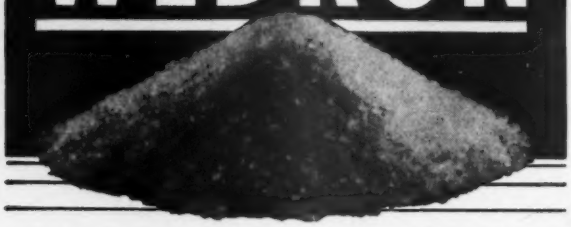

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At Wedron sand is at its best. The pure, white natural silica product from the famous Ottawa-Wedron deposits, is refined and processed to remove any trace of foreign matter. At our plant with its modern sand processing equipment nothing is left to chance. Your shipments are laboratory checked and inspected for purity and proper grain size. This insures uniform quality from shipment to shipment, year in and year out.

Wedron Silica is fully 99.9% pure, according to careful chemical analysis which is as follows: Silica—99.90%; Iron Oxide—.02%; Aluminum Oxide—.05%; Titanium Oxide—.015%; Calcium Oxide—.01%; and Magnesium Oxide—.005%.

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MINES AND MILLS IN THE OTTAWA WEDRON DISTRICT

WEDRON SILICA COMPANY

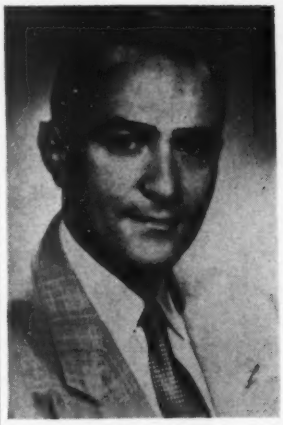
135 So. LaSalle Street, Chicago 3, Illinois

Application of Statistics . . .
(*Continued from page* 614)

Lastly, simple correlation, control limits and simple groupings of data helped to tie down the variable in glass production.

Statistics and quality control can be and are a very useful tool in the glass container industry. Every day new methods are being used in their application. Much work yet remains to be done in fields yet untouched, the only limiting factors being time and personnel.

J. M. LAMBERT IS RESEARCH AIDE



J. M. Lambert

Appointment of Dr. Joseph M. Lambert as assistant to the director of research for Pittsburgh Plate Glass Company's Glass Division research laboratory in Creighton, Pennsylvania, has been announced by Dr. James E. Archer, director of research.

Prior to his appointment Dr. Lambert had served as a senior fellow on a Pittsburgh Plate Glass Research Fellowship at Mellon Institute during the past three years. He initiated his work as a fellow at Mellon Institute in 1953.

A native of Vienna, Austria, Dr. Lambert received a Ph.D. in physics from the University of Vienna where he also completed a post doctoral fellowship in 1937.

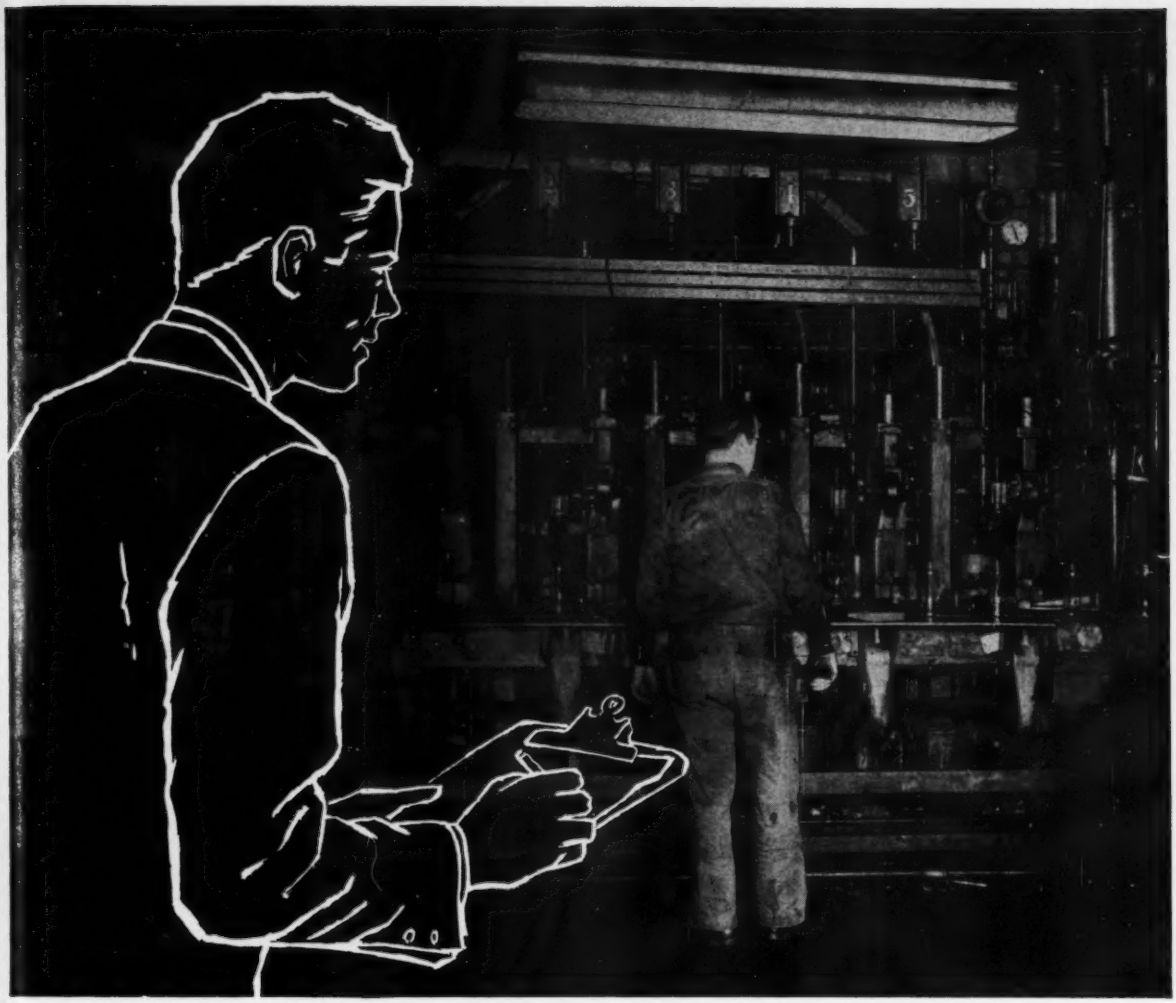
W. R. GREER RETIRES

W. Russell Greer of Pemco Corporation has retired from active duty. A well-known sales executive in the enameling industry, Mr. Greer has been active in the field and home office for Pemco Corporation for thirty-six years. Although he retires from active sales duty, he will continue on as a member of the board of directors for Pemco.

"Russ" Greer, as he became known in the porcelain enamel industry, began with the Porcelain Enamel and Manufacturing Company (Pemco) in 1921. After a year in the plant, he began selling porcelain enamel frits to other manufacturers, covering the entire country. In 1924, he becames sales manager of Pemco and later that year was made vice president in charge of sales.

Mr. Greer has been active on the outside as well as in the ceramic industry. He is a past president of the Sales Executives Council of Baltimore and a member of the National Sales Executives. He will continue as a director of the Pemco Corporation.

• Stockholders have approved merger of The Pfaudler Co., Rochester, New York, and the Permutit Company, New York City, under the name Pfaudler Permutit Inc. The merger has been accomplished by an exchange of common stock, giving Pfaudler shareholders 1.429 shares in the merged company for each share owned. Permutit stock has been exchanged on a share-for-share basis.



HOW THE SILICONES MAN HELPED...

STOP THE SMOKE IN A GLASS PLANT

Until recently, application of smoke-reducing silicones to glass forming machinery—especially the blank mold—presented problems that escaped solution. Smoke from ordinary lubricants caused imperfections in the product . . . created unpleasant working conditions . . . and the collected soot presented a fire hazard. Now, with the introduction of the FORMASIL Spray Kit, UNION CARBIDE Silicones can be used most effectively to eliminate these conditions!

The FORMASIL Spray Kit permits the automatic application of silicones on shears, in scoops, deflectors and blank molds. Developed by the UNION CARBIDE Silicones Man with the assistance of Wheaton Glass Company, Millville, N. J., the efficiency of the system was demonstrated and proven during a *two week production run!* Today, after four months of using silicones continuously, smoke, soot and dirt are greatly reduced . . . blank mold swabbing and changing decreased by better than 50 percent! The job speed increased and percent pack is equal to or better than any previous performance!

You can install the FORMASIL Spray Kit (includes all fittings and instructions) on your Hartford Empire I.S. machine. And, your UNION CARBIDE Silicones Man can give you data about kits under development for other types of glass forming equipment. Call the Silicones Man today . . . or write Dept. GL-11, Silicones Division, Union Carbide Corporation, 30 East 42nd Street, New York 17, N.Y.

UNION CARBIDE TRADE-MARK SILICONES

In Canada: Bakelite Company, Division of Union Carbide Canada Limited, Toronto 7, Ontario

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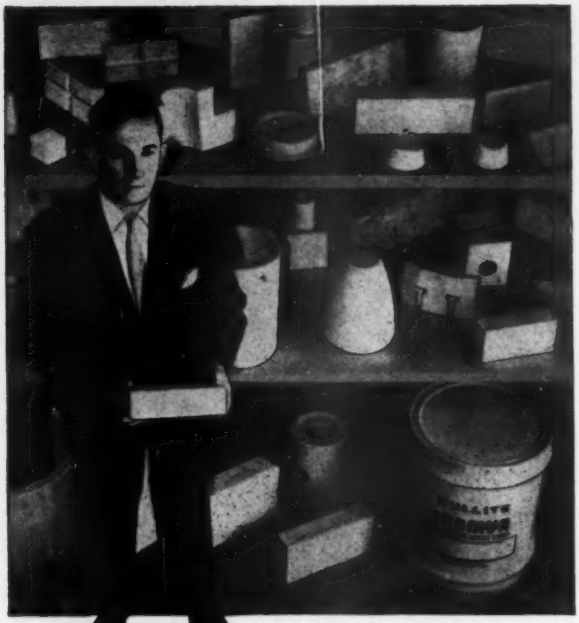

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For refractory economy...

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- high melting point
- high softening point
- minimum expansion
- resistance to spalling
- load bearing strength
- resistance to slag
- low heat conductivity
- chemical neutrality

You'll like the uniform high quality of SHAMVA Mullite super-refractory brick and special shapes. And you'll like the practical, economical answers to refractory problems The Man from Mullite can provide.

The Man from Mullite—a trained field engineer—is ready to recommend or develop SHAMVA Mullite Products for your particular service. Why not call him soon? For free brochures, write:
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HELP WANTED

PLANT MANAGER

Position open as manager to take complete charge of construction, staffing and operating the new Gallo Glass Co. now under construction at Modesto, California. Liberal compensation. Only persons of extensive experience will be considered. All inquiries will be strictly confidential. Send complete resume to Gallo Glass Co., P. O. Box 1230, Modesto, Calif.

HELP WANTED. Engineer familiar with Glass Tempering and capable of handling all phases of production. Reply to Box 208, The Glass Industry, 55 West 42nd Street, New York 36, N. Y.

GENERAL ELECTRIC TO PROVIDE HIGH-ACCURACY LEHR DRIVES

A major glass company has placed an order with General Electric for two high-accuracy window glass lehr drives. Value of the order is said to be approximately $46,500.

The specially-engineered control system will provide an accuracy of plus or minus one-quarter of one per cent. To aid in meeting the stringent reliability requirements of the glass industry, the speed regulator for the drive will be composed of non-rotating elements.

The automatically-controlled lehr drives will replace existing manual drives.

O-I TO BUILD VENEZUELA PLANT

Owens-Illinois Glass Company has announced plans to build a glass plant, its second outside the United States, near Valencia, Venezuela, to serve the Venezuelan market.

The plant will be constructed on a 79-acre site in Los Guayos, near Valencia, approximately 100 miles southwest of Caracas, the capital of Venezuela. It will bring the total number of Owens-Illinois plants to 53. Others are located in 19 states, Canada and Cuba.

Engineering and construction will be by Venezuelan firms, from preliminary designs made by the Owens-Illinois Administrative Engineering Department in Toledo.

Carl R. Megowen, president of Owens-Illinois, said the Venezuelan plant would be patterned after the company's newest factories in the United States, and would be equipped with the most modern manufacturing facilities. At the outset, it will employ about 120 persons, all Venezuelans except for a few technicians and supervisors assigned from O-I's existing operations staff.

The plant will be operated by Owens-Illinois de Venezuela, C. A., a new corporation established as a subsidiary. John L. Gushman, O-I vice president and general manager of the International Division, is president of Owens-Illinois de Venezuela, C. A., and Paul B. Stewart is vice president and general manager.

Construction is now under way on a glass container plant near Havana, Cuba. Other Western Hemisphere operations include a plywood veneer mill at Princeville, Quebec, Canada, and timberlands on Grand Bahama Island.